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Attachments	Total Number of Pages
Attachment I: Listing of Computer Files	4
Attachment II: One Compact Disc	N/A
Attachment III: Canister Handling Facility General Arrangement Drawings	12

RECORD OF REVISIONS

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1. PURPOSE

This design calculation revises and updates the previous criticality evaluation for the canister handling, transfer and staging operations to be performed in the Canister Handling Facility (CHF) documented in BSC [Bechtel SAIC Company] 2004 [DIRS 167614]. The purpose of the calculation is to demonstrate that the handling operations of canisters performed in the CHF meet the nuclear criticality safety design criteria specified in the *Project Design Criteria (PDC) Document* (BSC 2004 [DIRS 171599], Section 4.9.2.2), the nuclear facility safety requirement in *Project Requirements Document* (Canori and Leitner 2003 [DIRS 166275], p. 4-206), the functional/operational nuclear safety requirement in the *Project Functional and Operational Requirements* document (Curry 2004 [DIRS 170557], p. 75), and the functional nuclear criticality safety requirements described in the *Canister Handling Facility Description Document* (BSC 2004 [DIRS 168992], Sections 3.1.1.3.4.13 and 3.2.3). Specific scope of work contained in this activity consists of updating the Category 1 and 2 event sequence evaluations as identified in the *Categorization of Event Sequences for License Application* (BSC 2004 [DIRS 167268], Section 7).

The CHF is limited in throughput capacity to handling sealed U.S. Department of Energy (DOE) spent nuclear fuel (SNF) and high-level radioactive waste (HLW) canisters, defense high-level radioactive waste (DHLW), naval canisters, multicanister overpacks (MCOs), vertical dual-purpose canisters (DPCs), and multipurpose canisters (MPCs) (if and when they become available) (BSC 2004 [DIRS 168992], p. 1-1). It should be noted that the design and safety analyses of the naval canisters are the responsibility of the U.S. Department of the Navy (Naval Nuclear Propulsion Program) and will not be included in this document. In addition, this calculation is valid for the current design of the CHF and may not reflect the ongoing design evolution of the facility. However, it is anticipated that design changes to the facility layout will have little or no impact on the criticality results and/or conclusions presented in this document.

This calculation is subject to the *Quality Assurance Requirements and Description* (DOE 2004 [DIRS 171539]) because the CHF is included in the *Q-List* (BSC 2005 [DIRS 171190], p. A-3) as an item important to safety. This calculation is prepared in accordance with AP-3.12Q, *Design Calculations and Analyses* [DIRS 168413].

2. METHOD

2.1 CRITICALITY SAFETY ANALYSIS

The criticality safety calculations presented in this document evaluate the DOE SNF canisters in the CHF to ensure they meet the criticality safety requirements under normal conditions as well as for Category 1 and 2 event sequences, in accordance with 10 CFR 63 [DIRS 173273]. Further, this calculation determines the minimum spacing for the canister staging racks in the CHF and a controlled moderator height for defense in depth. The off-normal and accident conditions are inclusive of Category 1 and 2 event sequences as defined in 10 CFR 63.2 [DIRS 173273]. Moderator and reflector conditions are varied to find the most reactive configuration. The process and methodology for criticality safety analysis given in the *Preclosure Criticality Analysis Process Report* (BSC 2004 [DIRS 172058], Section 2.2.7) will be implemented in these calculations, and the following method will be followed:

- The design of the facility will be based on the most reactive fuel.
- The multiplication factor (k_{eff}), including all biases and uncertainties at a 95 % confidence level, will not exceed 0.95 under all credible normal, and Category 1 and 2 event sequences (NRC 2000 [DIRS 149756], Section 8.4.1.1).
- Conservative modeling assumptions will be considered leading to maximum reactivity for dimensional variables (e.g., pitch and manufacturing tolerances for canisters).
- Conservative modeling assumptions will also be used regarding materials in the fuel including no accounting for burnable poisons in fuel, no credit for ^{234}U and ^{236}U in fuel, no credit for fission products or transuranic absorbers in fuel, and use of the most reactive fuel stack density.
- Fixed neutron absorber used for criticality control can only be taken credit for up to 75% of the neutron absorbing material (NRC 2000 [DIRS 149756], Section 8.4.1.1).

Note that the terms “model(s)” and “modeling” as used in this calculation document refer to the geometric configurations of the criticality cases analyzed and not scientific models per LP-SIII.10Q-BSC, *Models* [DIRS 172972].

These calculations use the qualified software MCNP (Briesmeister 1997 [DIRS 103897] and CRWMS M&O 1998 [DIRS 154060]). MCNP is a three-dimensional Monte Carlo particle transport code with the capability to calculate eigenvalues for critical systems. The Nuclear Regulatory Commission (NRC) accepts MCNP in NUREG-1567 (NRC 2000 [DIRS 149756], p. 8-10) for criticality calculations.

2.2 ELECTRONIC MANAGEMENT OF INFORMATION

Electronic management of information generated from these calculations is controlled in accordance with Section 5.1.2 of AP-3.13Q, *Design Control* [DIRS 167460]. The computer input and output files generated from this calculation are stored on a Compact Disc (CD), and submitted as an attachment to this document (Attachment II).

3. ASSUMPTIONS

3.1 DOE SNF FUEL (DROP SCENARIOS)

Assumption: It is assumed that a drop of a DOE SNF canisters will not cause a breach in the CHF.

Rationale: DOE SNF standardized canisters can withstand, without breaching, a drop in any orientation from a height of 23 ft (7 m) onto an essentially unyielding flat surface per the *U.S. Department of Energy Spent Nuclear Fuel Canister Survivability* document (BSC 2004 [DIRS 168792], Section 6). Multicanister overpack (MCO) canisters can withstand, without breaching, a flat-bottom drop (3 degrees or less off vertical) from a height of 23 ft (7 m) and a drop in any orientation from a height of 2 ft (0.6 m) (individually–not both in sequence) onto an essentially unyielding flat surface (BSC 2004 [DIRS 168792], Section 6). These lifting heights are considered through requirement PRD-013/T-014 (Canori and Leitner 2003 [DIRS 166275], p. 3-63) since drop test performance (i.e., canisters surviving flat bottom drops from a height of 23 ft and a drops in any orientation from a height of 2 ft) of the DOE SNF canisters 'must be considered'. It is therefore reasonable to assume that the DOE SNF canisters will not breach during handling in the CHF.

Confirmation Status: This assumption requires no further confirmation based on the stated rationale.

Use in the Calculation: Sections 5.1.4, 6.3, and 6.4.

3.2 WASTE PACKAGE COMPONENTS MODELED AS RIGHT CYLINDERS

Assumption: It is assumed that the components, such as DOE SNF disposable canisters, tubes, end fittings, and fuel pins may be modeled as right prisms or right cylinders. In most cases, this was accomplished by conserving volume but changing geometry, i.e., replacing a region with an irregular shape of structural material with two cylindrical regions (one of structure and one of void) having the proper volumes. For a few other cases structural material was removed or fuel material was added to achieve a right prism or right cylinder (as in the case of dished fuel pellets modeled as right cylinders).

Rationale: This assumption is conservative. Geometry of structural material does not significantly affect reactivity as long as the approximate thickness is conserved. Removing structural material is conservative because the structural material is composed mainly of neutron absorbers, and hence its absence provides a higher value for the k_{eff} of the system. Addition of fuel material is conservative because it adds fissile material and increases the reactivity of the system. This assumption is made to simplify the MCNP calculation but does not significantly impact the results of the calculation.

Confirmation Status: This assumption requires no further confirmation based on the stated rationale.

Use in the Calculation: Section 5.1.4.

3.3 STRUCTURAL MATERIAL MAY BE NEGLECTED

Assumption: It is assumed that some components of the DOE SNF disposable canisters (such as baskets or structural material) may be neglected.

Rationale: This assumption is conservative since these components are composed primarily of neutron absorbers.

Confirmation Status: This assumption requires no further confirmation based on the stated rationale.

Use in the Calculation: Section 5.1.4.

3.4 HYDRAULIC FLUID COMPOSITION

Assumption: It is assumed that the hydraulic fluid used as an alternative moderator material was a conventional silicone fluid (polysiloxane fluid) with a degree of polymerization of four (Gelest 2004 [DIRS 169915], p. 11).

Rationale: The basis for this assumption is that the CHF design has not identified the hydraulic fluid for lubrication, but the candidate material used for lubrication is expected to be less effective moderator than water. The material used for this calculation to demonstrate criticality safety is a common silicone based hydraulic fluid (Gelest Inc. 2004 [DIRS 169915], p. 7). It should be recognized that this material might not represent the most reactive condition. Any change in the design selection of the hydraulic fluid would require re-evaluation of criticality safety to ensure that all the criticality design criteria are met.

Confirmation Status: This assumption requires no further confirmation based on the stated rationale.

Use in the Calculation: Section 5.1.4.

3.5 PINS IN IDENT-69 CANISTER ARE SIMILAR IN GEOMETRY TO PINS IN TYPE 4.1 DFA

Assumption: Exact dimensions for the fuel pins in the Ident-69 canister are not known. Only the outer cladding diameter is given in source references. It is assumed that the total volume of fuel in the source assembly is the same for the Ident-69 pins and the Type 4.1 DFA. It is further assumed that dimensions for the two fuel pins are similar: same length of each component including active fuel length and same cladding thickness.

Rationale: Given the number of fuel pins in each source assembly, an assumption of same volume and active fuel length results in a calculated fuel pellet diameter that is reasonable given the outer diameter of the Ident-69 fuel rods (*SNF.xls,* worksheet *FFTF*). Other dimensions such as total pin length and dimensions for structural components are not expected to significantly impact the reactivity of the fuel.

Confirmation Status: This assumption requires no further confirmation based on the stated rationale.

Use in the Calculation: Section 5.1.4.

3.6 ALUMINUM 3003 MAY BE MODELED AS ALUMINUM 6061

Assumption: For Fermi SNF, it is assumed that the end cups of the –04 canister (made of aluminum 3003) are made of aluminum 6061 like the main body of the canister.

Rationale: The volume of the end cups comprises a small fraction of the volume of the whole body of the –04 canister. The composition differences between aluminum 3003 and aluminum 6061 are neutronically insignificant. In addition, aluminum is a weak neutron absorber.

Confirmation Status: This assumption requires no further confirmation based on the stated rationale.

Use in the Calculation: Section 5.1.4.

3.7 DENSITY OF $GdPO_4$

Assumption: It is assumed that the density of $GdPO_4$ (anhydrous gadolinium phosphate) is 5 g/cm^3.

Rationale: No density is reported for $GdPO_4$. However, gadolinium is a rare earth element, and compounds formed by gadolinium will have similar properties to other rare earth compounds. The density of monazite (anhydrous rare earth phosphate containing a mix of rare earth elements) is reported as 5 – 5.3 g/cc (Weast, R.C., ed. 1972 [DIRS 127163], p. B-195). The density of $GdPO_4$ is expected to fall into this range. The lower bound of 5 g/cc was selected because this results in the smallest mass of Gd and is therefore conservative.

Confirmation Status: This assumption requires no further confirmation based on the stated rationale.

Use in the Calculation: Attachment II/*SNF.xls*, worksheet *Fermi*.

3.8 COMPOSITION OF PINS IN IDENT-69 CANISTER

Assumption: The exact isotopic composition for the fuel pins in the Ident-69 canister is not known. Only the Pu / U ratio is given in source references. It is assumed that the isotopic ratios of the isotopes of Pu and the isotopes of U are the same for the Ident-69 pins and the Type 4.1 driver fuel assembly (DFA). It is further assumed that the densities of Ident-69 and Type 4.1 fuel are the same.

Rationale: Based on the data in (INEEL 2002 [DIRS 158820], Table 1), the isotopic breakdowns of Pu and U are expected to be approximately the same for all fuels. Type 4.1 fuel has the highest ratio of Pu-239, which is conservative.

Confirmation Status: This assumption requires no further confirmation based on the stated rationale.

Use in the Calculation: Attachment II/*SNF.xls*, worksheet *FFTF*.

4. USE OF COMPUTER SOFTWARE

4.1 BASELINED SOFTWARE

4.1.1 MCNP

The MCNP code (CRWMS M&O 1998 [DIRS 154060]) was used to calculate the multiplication factor, k_{eff}, for all systems presented in this report. The software specifications are as follows:

- Program Name: MCNP (CRWMS M&O 1998 [DIRS 154060])
- Version/Revision Number: Version 4B2LV
- Status/Operating System: Qualified/HP-UX B.10.20
- Software Tracking Number: 30033 V4B2LV
- Computer Type: HP 9000 Series Workstations
- CPU Number: 700887

The input and output files for the various MCNP calculations are contained on a CD (Attachment II) and the files are listed in Attachment I.

The MCNP software used was: (1) appropriate for the criticality (k_{eff}) calculations, (2) used only within the range of validation as documented through Briesmeister (1997 [DIRS 103897]) and CRWMS M&O (1998 [DIRS 102836], Section 3.1), and (3) obtained from Software Configuration Management in accordance with appropriate procedures.

4.2 COMMERCIAL OFF-THE-SHELF SOFTWARE

4.2.1 MICROSOFT EXCEL 97 SR-2

- Title: Excel
- Version/Revision Number: Microsoft® Excel 97 SR-2
- This version is installed on a PC running Microsoft Windows 2000 with CPU number 503009

The file for the Excel calculation is contained on a CD (Attachment II) and the file is listed in Attachment I.

Excel was used to calculate weight fractions and weight percent. The calculations can be reproduced and checked by hand. Excel is exempt from qualification per Section 2.1.6 of LP-SI.11Q-BSC, *Software Management* [DIRS 171923].

5. CALCULATION

All technical product inputs and sources of the inputs used in the development of this calculation are documented in this section. Attachment III features general arrangement drawings of the CHF as of the date of this calculation, and may not reflect the ongoing design evolution. The purpose of these drawings is to show the functional areas where the canisters will be handled and staged and to show the moderator controlled areas.

5.1 CALCULATIONAL INPUTS

5.1.1 Design Requirements and Criteria

The design criteria for criticality safety analysis provided in Section 4.9.2.2 of the *Project Design Criteria Document* (BSC 2004 [DIRS 171599]) are used in these calculations. The pertinent criteria for CHF criticality safety include the following (BSC 2004 [DIRS 171599], Section 4.9.2.2):

- The multiplication factor, k_{eff}, including all biases and uncertainty at a 95 percent confidence level, shall not exceed 0.95 under all normal conditions, and Category 1 and Category 2 event sequences.

- For fixed-neutron absorbers used for criticality control such as grid plates or inserts, no more than 75 percent credit of the neutron absorber content is used for preclosure criticality analyses, unless standard acceptance tests verify that the presence and uniformity of the neutron absorber are more effective.

The *Project Requirements Document* seeks to 'prevent unplanned nuclear criticality events' through requirement PRD-015/P-096 (Canori and Leitner 2003 [DIRS 166275], p. 4-206). From an operational/performance requirement point of view, 'the staging racks … shall be designed to maintain criticality safety' per the *Project Functional and Operational Requirements* document (Curry 2004 [DIRS 170557], Section 1.1.6-4). The functional requirement 3.1.1.3.4.13 of the *Canister Handling Facility Description Document* (BSC 2004 [DIRS 168992], p. 3-22) states that the "canister staging pit geometry shall prevent criticality". The criteria for this requirement is that the "facility shall provide space, layout, and barriers as required to ensure moderator control in criticality sensitive areas" and that piping containing moderator "shall be routed around criticality sensitive area". Further, functional requirement 3.2.3.1 (BSC 2004 [DIRS 168992], p. 3-28) states that the "facility shall be designed and operated to prevent any credible criticality event from occurring". The basis for this requirement is to prevent nuclear criticality events, in accordance with DOE nuclear facility safety programs.

5.1.2 DOE SNF Types

Criticality evaluations are presented in this document for DOE fuel, which has been categorized into nine fuel groups (Mecham, D.C. 2004 [DIRS 170673], Section 4.2.4.1). A representative fuel type is chosen as bounding case for each group. Table 5.1-1 shows the nine DOE fuel groups and their corresponding representative fuel.

Table 5.1-1 DOE Fuel Groups and Representative Fuel Types

Group Number	DOE Fuel Type [a]	Representative Fuel
1	Uranium Metal	N-Reactor
2	Uranium-Zirconium/Uranium-Molybdenum	Enrico Fermi
3	Uranium Oxide (High Enriched Uranium)	Shippingport Pressurized Water Reactor (PWR)
4	Uranium Oxide (Low Enriched Uranium)	Three Mile Island (debris)
5	Uranium-Aluminum	Advanced Test Reactor (ATR)
6	Uranium/Thorium/Plutonium Carbide	Fort St. Vrain
7	Mixed Oxide	Fast Flux Test Facility (FFTF)
8	Uranium/Thorium Oxide	Shippingport Light Water Breeder Reactor (LWBR)
9	Uranium-Zirconium-Hydride	Training Research Isotopes General Atomics (TRIGA)

[a] Source data from Mecham, D.C. 2004 [DIRS 170673], Section 4.2.4.1

5.1.3 Upper Subcritical Limit

The definition of upper subcritical limit (USL) is (BSC 2004 [DIRS 172058], Section 3.5):

$$k_S + \Delta k_S \leq USL \qquad (1)$$

where k_S is the MCNP calculated value for the system, Δk_S is an allowance for (a) statistical or convergence uncertainties, or both in the computation of k_s, (b) material and fabrication tolerances, and (c) uncertainties due to the geometric or material representations used in the computational method [Note: allowance for items (b) and (c) can be obviated by using bounding representations].

Per ANS-8.7/ANSI N16.5 [DIRS 144741], the calculated k_{eff} for a fissile system is considered to be acceptable provided the calculated k_{eff} plus 2 sigma is less than a specified USL. The *Benchmark and Critical Limit Calculation for DOE SNF* (BSC 2002 [DIRS 161781], Section 6.3) document establishes a USL of 0.9631 for DOE fuel based on the statistical averaging method. Applying a 0.05 administrative margin (BSC 2004 [DIRS 172058], Section 3.4.1), the final USL for the calculations presented in this document is 0.9131.

5.1.4 DOE SNF Calculation Inputs

The descriptions of the fuel loading in the MCO canisters and DOE SNF standardized canisters in the following subsections are taken from the most current criticality analyses and design documents (unless otherwise noted). Since the DOE SNF canisters arrive sealed at the CHF (Section 1) and are assumed to not breach (Assumption 3.1), the DOE SNF canisters are modeled as dry on the inside. For defense in depth, however, the most reactive DOE fuel types are modeled with moderator (partially and fully flooded) on the inside.

5.1.4.1 N-Reactor Fuel and Canister Description

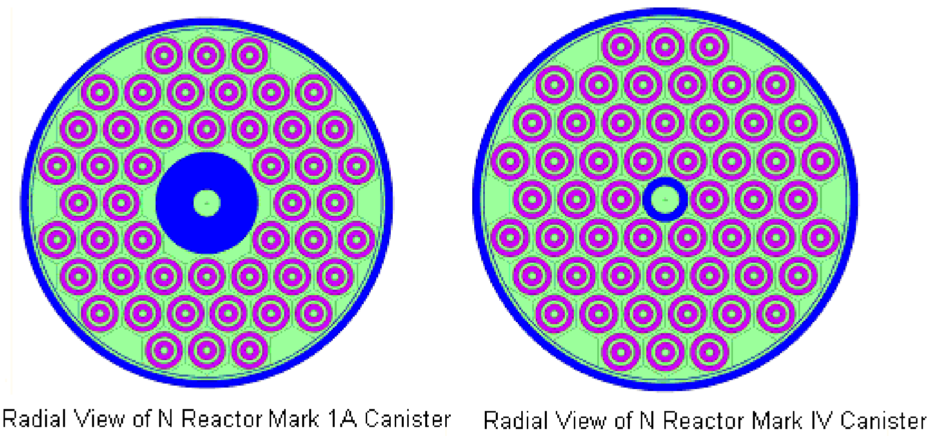
The MCNP input model representing N-Reactor fuel in a canister utilized the existing MCNP input files 4zv0111 and 1zv0111 from the *Intact and Degraded Component Criticality Calculations of N Reactor Spent Nuclear Fuel* (CRWMS M&O 2001 [DIRS 153262]) document as a starting point for the present calculations. The previously existing MCNP input files were stripped of the waste package (WP) and surrounding HLW canisters so that only the DOE canister itself was contained and modeled in the present MCNP input files.

Two types of fuel were considered: Mark IV fuel and Mark 1A fuel. Figure 5.1-1 presents the radial view of the DOE canisters containing Mark IV and Mark 1A fuel. One Mark IV fuel element contains a maximum of 16.0 kg of 0.947 % enriched uranium in the outer tube and 7.5 kg of 0.947 % enriched uranium in the inner tube (DOE 2000 [DIRS 150095], Table 3-1). The multi-canister overpack (MCO) contains up to 54 fuel elements stacked in five layers (DOE 2000 [DIRS 150095], pp. 23-25). The fuel tubes are 60.96 mm in diameter (DOE 2000 [DIRS 150095], Table 3-1) and they are close packed in the disposal canister.

The Mark 1A fuel element is enriched to 1.25 % U-235 in the outer tube (DOE 2000 [DIRS 150095], Table 3-1) and there are 48 fuel elements in the canister with the center post being 6.625 inch outer diameter (OD) versus 2.835 inch OD for Mark IV (DOE 2000 [DIRS 150095], Figure 4-2). The outer fuel tube is 6.096 cm diameter on the outside, 4.496 cm diameter on the inside and it is 53 cm long (DOE 2000 [DIRS 150095], Table 3-1). The cladding is 0.0635 cm thick on the outside and 0.0555 cm thick on the inside (DOE 2000 [DIRS 150095], Table 3-2). Similarly, the inner tube is 3.175 cm diameter on the outside, 1.118 cm diameter on the inside and it is 53 cm long (DOE 2000 [DIRS 150095], Table 3-1). The cladding is 0.1015 cm thick on the outside and 0.0635 cm thick on the inside (DOE 2000 [DIRS 150095], Table 3-2).

The canister design (MCO with no neutron absorber) includes a nominal length of 4198.37 mm (165.29 in.) and a maximum outer diameter of 642.9 mm (25.31 in.) (CRWMS M&O 2001 [DIRS 153262], p. 14). Beyond these basic dimensions, fuel-specific internals (also called baskets) have been designed for each canister based on the known maximum lengths of the fuels (Mark IV or 1A) contained therein. The MCOs are constructed out of 304L stainless steel having an outside diameter 60.92 cm (23.985 in.) and a wall thickness of 1.27 cm (0.5 in.) (CRWMS M&O 2001 [DIRS 153262], p. 14). The top portion of the MCO has a slightly larger diameter of 64.29 cm (25.31 in.) than the overall tube, the overall length of the MCO is 422.707 cm (166.42 in.) with an inner cavity height to the top of the stacked baskets of 356.545 cm (140.372 in.), and the bottom plate has a thickness of 5.11 cm (2.01 in.) (CRWMS M&O 2001 [DIRS 153262], p. 14). There is a metal “structure” that adds another 57.91 cm (22.80 in.) to the top of the MCO above the top basket (CRWMS M&O 2001 [DIRS 153262], p. 14). This structure is not represented in these calculations and the bottom plate is represented with a thickness of 4.4704 cm.

It should also be mentioned that a central process post constructed out of 304L stainless steel is present in the MCOs. In the case of the Mark IV fuel baskets, the post outer diameter is 7.20 cm (2.835 in.) with a 1.37 cm (0.54 in.) thick wall. The Mark 1A fuel use a 16.83 cm (6.625 in.) diameter post with a 4.458 cm (1.755 in. [max.]) hole drilled in the center for a 6.18 cm (2.435 in.) wall thickness (DOE 2000 [DIRS 150095], Figure 4-2).



NOTE: Figure not to scale.

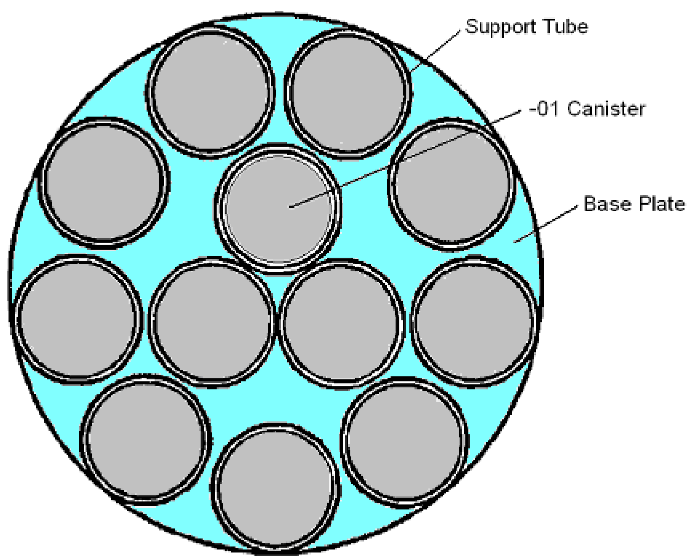
Figure 5.1-1 Radial View of DOE Canisters Containing Mark IV and Mark 1A Fuel

5.1.4.2 Enrico Fermi Fuel and Canister Description

The MCNP input model representing Enrico Fermi fuel in a canister utilized the existing MCNP input file can3 from the *Criticality Potential of Intact DOE SNF Canisters in a Misloaded Dry Waste Package* (BSC 2004 [DIRS 172201]) document as a starting point for the present calculations. The boundary conditions were the only changes made to the previously existing MCNP input files (see Section 5.2 for description of boundary conditions).

Fermi fuel is packaged as loose pins contained in two concentric DOE SNF shipping canisters. The fuel pins are made of uranium/molybdenum alloy (approximately 10 wt% molybdenum alloyed with uranium of 25.69% U-235 enrichment) (DOE 1999 [DIRS 104110], Section 3). The fuel is contained by zirconium cladding, and there are no gaps between the cladding and the fuel. Zirconium fuel pin tips are swaged onto the ends of the fuel pin. The Fermi fuel pins are placed inside canisters known as "–04" canisters, which were in turn placed in "–01" canisters. Each –01 canister contains one –04 canister, and each –04 canister contains 140 loose fuel pins with no supporting or spacing mechanism. The –01 and –04 canisters are made from 6061 aluminum, except for the end plugs of the –04 canister which are fabricated from 3003 aluminum. For this calculation, the end plugs of the –04 canister are also assumed to be of 6061 aluminum (Assumption 3.6). The –01 shipping canisters with all their contents are placed into the short DOE standardized SNF canister with the twelve support tubes welded to a base plate (CRWMS M&O 1999 [DIRS 104118], Section 5). The plate-and-tube assembly is then placed into the DOE standardized SNF canister and the –01 canisters are placed into the tubes and the gaps are filled with iron shot containing a percentage of $GdPO_4$. This shot is poured between the –01 canisters and the tubes and between the tubes and the DOE standardized SNF canister. A second plate-and-tube assembly is placed in the DOE standardized SNF canister using the same method, for a total of 24 –01 canisters per DOE standardized SNF canister. The two layers are topped with a spacer plate and a spacer before the DOE standardized SNF canister is sealed. Figure 5.1-2 shows the radial view of the Fermi DOE SNF canister.

The geometry of the Fermi fuel and SNF contents has been simplified to adapt the geometry to right cylinders (Assumption 3.2). In addition, the fuel pins were rearranged into a hexagonal-pitch array (a more conservative arrangement). A comparison of the actual dimensions of the Fermi fuel and canister with the dimensions used in the MCNP cases can be found in Table 5.1-2. Note that this calculation considers support tubes made of Ni-Gd alloy and a loading of 3% by volume $GdPO_4$ in the iron shot. The compositions of the support tubes, Fermi fuel, and iron shot are calculated in *SNF.xls*, worksheets *Ni-Gd alloy* and *Fermi*.



NOTE: Figure is not to scale.

Figure 5.1-2 Radial View of the Enrico Fermi DOE SNF Canister

Table 5.1-2 Fermi Fuel and Packaging Dimensions and Materials

Component	Material [a]	Parameter	Actual Dimension (mm) [a]	Dimension Used (mm)
Fuel	U/Mo Alloy	Outer Diameter	3.7592	3.7592
		Length	774.70	774.7000
Cladding	Zirconium	Inner Diameter	3.7592	3.7592
		Outer Diameter	4.0132	4.0132
		Inner Length	774.70	774.7000
		Outer Length	781.9390	774.7000
Entire Fuel Pin	--------------	Pin Pitch	Varies (loose)	4.0132 (hexagonal)
-04 Canister Walls	Aluminum 6061	Inner Diameter	66.548	66.5480
		Outer Diameter	69.85	69.8500
-04 Canister Top Plug	Aluminum 6061 (Assumption 3.6)	Total Length	50.8	50.8000 [c]
		Thickness	1.651	1.6510 [c]
-04 Canister Bottom Plug	Aluminum 6061 (Assumption 3.6)	Total Length	25.4	25.4000 [c]
		Thickness	1.651	1.6510 [c]
Entire -04 Canister	--------------------	Inner Length	825.5	825.5000
		Outer Length	901.7	828.8020 [c]
-01 Canister Walls	Aluminum 6061	Inner Diameter	76.2	76.2000
		Outer Diameter	82.55	82.5500
-01 Canister Top Fitting	Aluminum 6061 [d]	Total Length	101.6 (estimated)	101.6000
		Lid Thickness	12.7	12.7000
-01 Canister Bottom Fitting	Aluminum 6061 [d]	Total Length	25.4	25.4000
		Lid Thickness	12.7	12.7000
Entire -01 Canister	--------------------	Inner Length	952.5 (approx)	952.5000
		Outer Length	1079.5	977.9000 [d]
Support Tubes	Ni-Gd alloy [e]	Inner Diameter	92.0 [f]	92.0000
		Outer Diameter	101.6 [f]	101.6000
		Length	1100.0 [f]	1100.0000
		Pitch	Not uniform (see Figure 5.1-2) [f]	Not uniform (see Figure 5.1-2)
Base/Spacer Plate	SS 316L	Diameter	426 [f]	438.1500
		Thickness	9.5 [f]	9.5000
Spacer	Void [g]	Length	335.5 [f]	335.5000
Void over Spacer	Void	Length	11 [f]	11.0000
Short Standardized SNF Canister	SS 316L [b]	Inner Diameter	430 (min) [b]	438.1500
		Inner Length	2540 (min) [b]	2575.0000

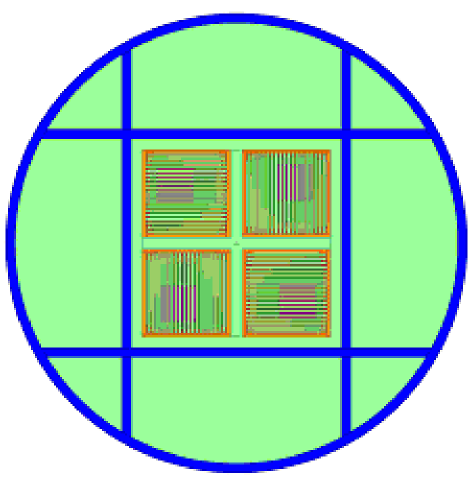
[a] Source data from DOE 1999 [DIRS 104110], Section 3 and Section 4 unless otherwise stated.
[b] Source data from DOE 1999 [DIRS 140225], Sections 3.2.3 (material) and 3.2.2 (dimensions).
[c] The –04 canister end plugs were modeled as a lid with the same thickness as the plug material and an adjacent region of void for the remainder of the hollow plug length (Assumption 3.6).
[d] The –01 end fittings were modeled as a solid lid and an adjacent void region for the remainder of the fitting length (Assumption 3.3). Iron shot is conservatively excluded from this void region.
[e] Specified in DOE 1999 [DIRS 104110], Section 4.1 as steel. Ni-Gd alloy was substituted.
[f] Source data from CRWMS M&O 1999 [DIRS 104118], Attachment 3.
[g] Specified in CRWMS M&O 1999 [DIRS 104118], Attachment 3 as SS 316L. The spacer is hollow, so void was substituted (Assumption 3.3).

5.1.4.3 Shippingport PWR Fuel and Canister Description

As a starting point for the present Shippingport PWR calculations, the existing MCNP input file spdds00 was utilized from the *Canister Handling Facility Criticality Safety Calculations* (BSC 2004 [DIRS 167614], which initially originated from the *Intact and Degraded Criticality Calculations for the Codisposal of Shippingport PWR Fuel in a Waste Package* (CRWMS M&O 2000 [DIRS 144714]) document.

One Shippingport PWR fuel cluster contains 19.5 kg of U-235 with an enrichment of 93.2% (DOE 1999 [DIRS 104940], Table 3-1). The fuel is a mixture of UO_2-ZrO_2-CaO (DOE 1999 [DIRS 104940], p. 6). The most reactive fuel consists of 54.9 wt% UO_2, 39.9 wt% ZrO_2 and 5.2 wt% CaO (DOE 1999 [DIRS 104940], Table 3-2). The canister contains only one fuel cluster and there is no added neutron absorber in the canister. Figure 5.1-3 presents the radial view of the DOE canister containing Shippingport PWR fuel.

The DOE SNF canister is a right circular cylinder pipe made of stainless steel (Type 316L or UNS S31603) with an outside diameter of 457.2 mm (18 in.) and a wall thickness of 9.525 mm (0.375 in.) (CRWMS M&O 2000 [DIRS 144714], p. 15). The nominal internal length of the DOE SNF canister reserved for fuel loading is 268.09 cm with a 19 mm thick base plate and a 9.5 mm thick top spacer plate (CRWMS M&O 2000 [DIRS 144714], p. 15). The nominal internal length of the empty space above the top spacer plate to the impact plate is 140.75 cm and the inner radius of the spacer cylinder in the empty space is 20.615 cm with a thickness of 0.635 cm (CRWMS M&O 2000 [DIRS 144714], p. 15). The canister also contains 9.5 mm thick stainless steel (Type 316L) guide plates that are used to hold the Shippingport PWR SNF cluster (CRWMS M&O 2000 [DIRS 144714], p. 15).



Radial View of Shippingport PWR Canister

NOTE: Figure is not to scale.

Figure 5.1-3 Radial View of DOE Canister Containing Shippingport DOE Fuel

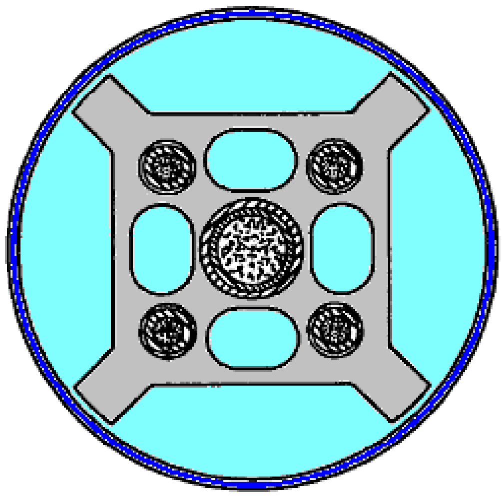
5.1.4.4 TMI-2 Fuel and Canister Description

The MCNP input model representing TMI-2 fuel in a canister utilized the existing MCNP input file can9 from the *Criticality Potential of Intact DOE SNF Canisters in a Misloaded Dry Waste Package* (BSC 2004 [DIRS 172201]) document as a starting point for the present calculations. The boundary conditions were the only changes made to the previously existing MCNP input files (see Section 5.2 for description of boundary conditions).

TMI fuel debris originates from TMI Unit 2 (TMI-2) where the typical fuel assembly installed in the reactor was a 15 x 15 Babcock & Wilcox PWR fuel assembly. Each fuel assembly contained an average of 208 fuel pins. The fuel was uranium oxide with a U-235 enrichment of 2.96%, 2.64%, or 1.98% weight percent (DOE 2003 [DIRS 164970], pp. 19-23). The fuel was formed into dished, chamfered pellets that were then placed into Zircaloy-4 cladding to form fuel pins. The fuel pins were loaded into an assembly structure formed of stainless steels (304 or 304L or 316), Zircaloy-4, and Inconel 718. During the TMI cleanup, debris from damaged fuel assemblies was packaged into canisters. The physical dimensions of the canisters are such that not more than a single, intact assembly could be stored in any one canister. The exact contents and fuel arrangement for each canister are unknown. For these criticality calculations, the amount of material in a TMI container is taken to be the fuel contained in one entire assembly at a beginning of life (BOL) enrichment of 2.96% (463.63 kg of U, including 13.72 kg of U-235, with a UO_2 density of 95% theoretical density). Although structural materials are present in the canisters, it is conservative to neglect them. The presence of any assembly structural materials is ignored for this calculation (Assumption 3.3).

Three types of canisters were used to package the TMI fuel debris: defueling, knockout, and filter. Based on the results of previous criticality analyses presented in the *Intact and Degraded Mode Criticality Calculations for the Codisposal of TMI-2 Spent Nuclear Fuel in a Waste Package* document (BSC 2004 [DIRS 168935], p. 53), the knockout (KO) canister has been judged to be the most reactive and will be the only type considered in this calculation. The KO canister is fabricated from 300 series stainless steels, predominantly 304L. It is based around a 14 in. Schedule 10 pipe with a reversed dish head forming the bottom of the canister. The top of the canister is a metal plate with penetrations and hardware for hydraulic loading and dewatering. The internal assembly for the KO canisters is designed to support five internal tubes filled with boron carbide (B_4C) poison pellets: one large center “A” tube and four outer “B” rods. Seven intermediate support plates or “spiders” are held in place by the poison rods, which in turn rest on one bottom support plate. A cross-section of the KO canister is shown in Figure 5.1-4.

Note that for these calculations, the fuel fills the available area of the KO canister up to a calculated height. The geometry of the TMI fuel and SNF contents has been simplified to adapt the geometry to right cylinders (Assumption 3.2). A comparison of the actual dimensions with the dimensions used in the MCNP cases can be found in Table 5.1-3. The fuel composition is calculated in *SNF.xls,* worksheet *TMI*.



NOTE: Figure is not to scale.

Figure 5.1-4 Radial View of DOE KO Canister Containing TMI-2 Fuel

Table 5.1-3 TMI-2 Fuel and Packaging Dimensions and Materials

Component	Material [a]	Parameter	Actual Dimension (mm) [a]	Dimension Used (mm)
Fuel				
Fuel Pellet	UO_2, 2.96 wt% U-235	Outer Diameter	9.362 (0.3686 in.) [b]	Modeled as filling the available area of the KO canister for a height of 59.609 cm, centered in the can. Calculations are shown in *SNF.xls*, worksheet *TMI.*
		Length	11.049 (0.435 in.) [b]	
		Geometry	Dished / chamfered [b]	
		Active Fuel Length / Rod	3601.7 (141.8 in.) [b]	
		Number of Pellets / Rod	~ 326 (estimated)	
		Number of Fuel Rods / Assembly	208 [b]	
		Mass Fuel / Assembly	525.95 kg (1159.53 lb) [b]	525.95 kg
Assembly Structure	Various	Width	216.81 (8.536 in.) [b]	Neglected per Assumption 3.3
		Length	4206.88 (165.625 in.)[b]	
KO Canister Internals				
KO Canister Center Support	SS 304L	Inner Diameter	57.175 (calculated)	57.175
		Outer Diameter	73.025 (2.875 in.)	73.025
		Thickness	7.925 (0.312 in.)	7.925
		Length	3371.85	3371.850
KO Canister Poison Tube A	SS 316L	Inner Diameter	50.673 (calculated) [c]	50.673
		Outer Diameter	53.975 (2.125 in.) [c]	53.975
		Thickness	1.651 (0.065 in.)	1.651
		Length	Not explicitly given	3327.400
KO Canister Poison Stack A	B_4C	Outer Diameter	49.657 (1.955 in.)	Neglected for conservatism
		Length	Not explicitly given	
KO Canister Poison Tubes B	SS 316L	Inner Diameter	20.65 (calculated)	20.650
		Outer Diameter	33.35	33.350
		Thickness	6.35	6.350
		Length	3327.4 (min)	3327.400
		Number of Stacks	4	4
		Location	63.50 mm from center in x and y directions	63.50 mm from center in x and y directions
KO Canister Poison Stacks B	B_4C	Outer Diameter	19.558 (0.770 in.)	Neglected for conservatism
		Length	Not explicitly given	
Intermediate Support Plates	SS 304L	Outer Diameter	Not explicitly given	Neglected per Assumption 3.3
		Thickness	12.7	
		Number of Plates	7	
		Pitch	400.05 mm (15.75 in.)	
Base Support Plate	SS 304L	Outer Diameter	340.52	340.520
		Thickness	31.75	31.750
		Location	127 mm from bottom of KO canister	127 mm from bottom of KO canister

Table 5.1-3 TMI-2 Fuel and Packaging Dimensions and Materials (cont.)

KO Canister				
KO Canister Walls	SS 304L	Inner Diameter	342.9 (calculated)	342.900
		Outer Diameter	355.6	355.600
		Thickness	6.35	6.350
KO Canister Top	SS 304L	Outer Diameter	355.6	335.600
		Thickness	101.6	101.600
		Top Skirt Length	101.6	101.600
KO Canister Bottom	SS 304L	Outer Diameter	355.6	335.600
		Thickness	9.525	9.525
		Geometry	Reverse dish	Right cylinder with void region
Entire KO Canister	-------------	Outer Length	3803.65	3803.650
		Inner Cavity Length	~3475 (estimated)	3473.450
DOE Standardized SNF Canister and Internals				
Centering Device	Carbon Steel	Inner Diameter	393.7 (calculated)	393.700
		Outer Diameter	406.4 (16 in.)	406.400
		Thickness	6.35 (0.25 in.)	6.350
		Length	Not explicitly given	4117.000
Long Standardized SNF Canister	SS 316L [d]	Inner Diameter	430 (min) [d]	438.150
		Inner Length	4114.8 (min) [d]	4117.000

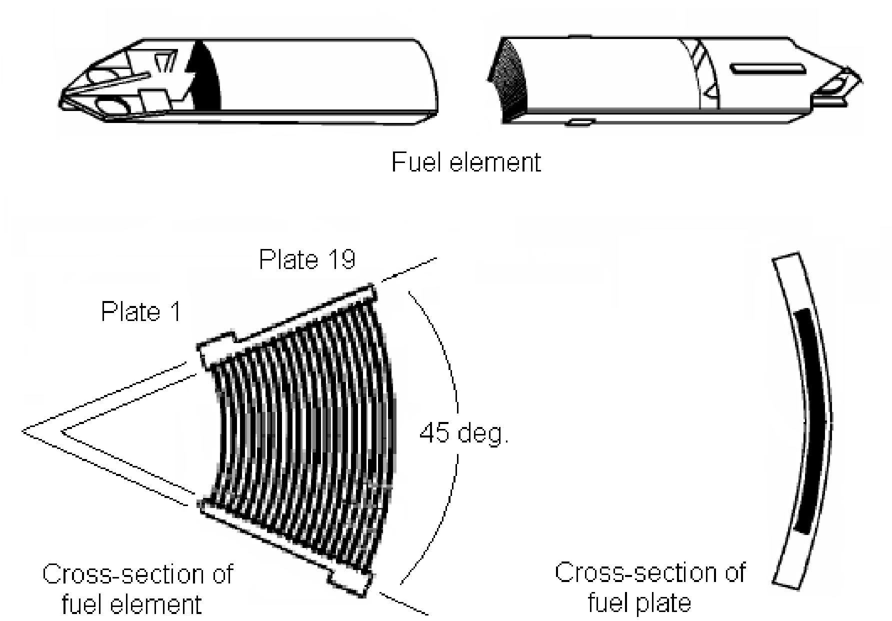
[a] Source data from DOE 2003 [DIRS 164970], Sections 3.1, 3.2, and 4.1.4, except where specified.
[b] Source data from DOE 2003 [DIRS 164970], Appendix B, column for Ref B-1.
[c] The source document DOE 2003 [DIRS 164970] lists conflicting values of 2.125 in. for the inner diameter of poison tube A (Section 3.2.3.1) and 2.125 in. for the outer diameter of poison tube A (Figure 3). 2.125 in. was chosen as the outer diameter so that poison tube A would fit inside the center support tube.
[d] Source data from DOE 1999 [DIRS 140225], Sections 3.2.3 (material) and 3.2.2 (dimensions)

5.1.4.5 Advanced Test Reactor (ATR) Fuel and Canister Description

The Advanced Test Reactor fuel is intended for disposal in the short DOE standardized SNF canister and the 5-DHLW/DOE SNF short waste package. The description of the ATR fuel is from the *Specification for Advanced Test Reactor Mark VII Zone Loaded Fuel Elements* report (INEEL 2003 [DIRS 171506]). The description of the loading of ATR fuel into the DOE standardized SNF canister is from *Packaging Strategies for Criticality Safety for "Other" DOE Fuels in a Repository* (DOE 2004 [DIRS 170071]). All ATR fuel and canister-related information is from these references unless otherwise noted.

For this calculation, the ATR fuel elements denoted ATR-7F were used. This is the same fuel element used in *Intact and Degraded Mode Criticality Calculations for the Codisposal of ATR Spent Nuclear Fuel in a Waste Package* (BSC 2004 [DIRS 171926], Section 5.1.1) and is the ATR fuel element with the highest fissile loading (Paige, B.E. 1969 [DIRS 167978], pp. 29, 35, 39, and 43). The specified fissile loading is 1075 g U-235 ±10 g (INEEL 2003 [DIRS 171506], p. 20).

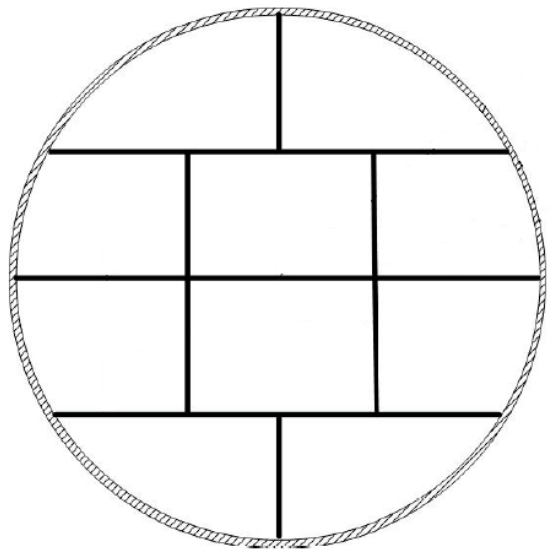
The ATR-7F fuel element consists of 19 concentric curved fuel plates held in place by aluminum 6061 side plates and aluminum 356 end boxes to form a curved fuel element. Each plate consists of uranium aluminide (UAl_x) fuel, with a uranium enrichment of 93 ± 1 wt% U-235 and a uranium-to-aluminum ratio that varies from plate to plate. Some of the fuel plates also contain integrated B_4C as a poison, but this is conservatively neglected for the current analysis. The fuel plates are clad in aluminum 6061. When the fuel plates are assembled, the angle of curvature of the fuel element is 45 degrees. Water gaps are present between each of the concentric plates. A diagram of the fuel element is provided in Figure 5.1-5, and dimensions are given in Table 5.1-4 and Table 5.1-5.



NOTE: Figure is not to scale.

Figure 5.1-5 ATR Fuel Element

Prior to disposal in the DOE standardized SNF canister, the upper and lower end boxes are removed. The remainder of the fuel element is placed into the DOE standardized SNF canister as follows (DOE 2004 [DIRS 170071], pp. 53-55). A basket assembly made of Ni-Gd alloy and SS 304L is placed into the SNF canister. This basket, shown in Figure 5.1-6, can accommodate 10 ATR fuel elements. After the fuel elements are loaded, a circular plate of SS 304L is placed on top of the basket. A second basket assembly is then loaded into the SNF canister and filled with an additional 10 fuel elements. Dimensions of the basket assembly are given in Table 5.1-4. The fuel core composition is calculated in *ATR.xls*, worksheet *Fuel Compositions*.



NOTE: Figure not to scale.

Figure 5.1-6 Basket for ATR Fuel Elements

Table 5.1-4 ATR Fuel and Packaging Dimensions and Materials

Component	Material	Parameter	Actual Dimension (mm)	Dimension Used (mm)
Fuel Element [a]				
Fuel Plate Cores	UAl_x / Al powder/ B_4C	Length	1200.404 (47.26 in.) to 1238.504 (48.76 in.)	1238.504 (48.76 in.)
		Radius	See Table 5.1-5	As in Table 5.1-5
		Width	See Table 5.1-5	As in Table 5.1-5
		Thickness	0.508 (0.020 in.) [c]	0.508 (0.020 in.) [c]
Fuel Plate Cladding	Aluminum 6061	Length	1256.919 (49.485 in.) to 1257.681 (49.515 in.)	1257.300 (49.500 in.)
		Radius	See Table 5.1-5	As in Table 5.1-5
		Width	See Table 5.1-5	As in Table 5.1-5
		Thickness	See Table 5.1-5	As in Table 5.1-5
Fuel Plate Gap	Void	Radial Thickness	See Table 5.1-5	As in Table 5.1-5
Side Plates	Aluminum 6061	Length	1256.919 (49.485 in.) to 1257.681 (49.515 in.)	1257.300 (49.500 in.)
		Width	62.154 (2.447 in.)	62.154
		Inner Radius	Not explicitly given	75.286 (2.964 in.)
		Outer Radius	Not explicitly given	140.030 (5.513 in.)
SNF Internals [b]				
Basket Sleeve	SS 304L	Inner Diameter	426.136 (calculated)	426.136
		Outer Diameter	429.25	429.250
		Length	Not explicitly given	1260.000
Basket Plates	C-4 Alloy (Ni-Gd Alloy)	Length	Not explicitly given	1260.000
		Thickness	9.525	9.525
		Horizontal Spacing	136.5 mm apart	136.500 mm apart
		Vertical Spacing	101.1 mm apart	101.100 mm apart
Spacer Plate	SS 304L	Outer Diameter	Not explicitly given	438.150
		Thickness	6.35 to 9.525	9.525
Short Standardized SNF Canister	SS 316L [d]	Inner Diameter	430.0 (min) [d]	438.150 [d]
		Inner Length	2540.0 (min) [d]	2575.000 [d]

[a] Source data from INEEL 2003 [DIRS 171506], except where noted.
[b] Source data from DOE 2004 [DIRS 170071], pp. 53-55, except where noted.
[c] Source data from Paige, B.E. 1969 [DIRS 167978], p. 38 as referenced by p. 39.
[d] Taken from Table 5.1-2.

Table 5.1-5 Dimensions for Individual ATR Fuel Plates

Plate #	Inner Radius of Plate (cm) [a]	Total Radial Thickness of Plate (cm) [b]	Gap Between This Plate and Next (cm) [b]	Arc Length of Fuel Plate Between Side Plates (cm) [c]	Min. Arc Length From Side Plate to Fuel Core (cm) [b]
Side	N/A	N/A	0.12954 (0.051 in.)	N/A	N/A
1	7.6581 (3.015 in.)	0.20320 (0.080 in.)	0.19812 (0.078 in.)	5.0641 (1.994 in.)	0.36830 (0.145 in.)
2	8.0594 (3.173 in.)	0.12700 (0.050 in.)	0.19812 (0.078 in.)	5.3793 (2.118 in.)	0.11430 (0.045 in.)
3	8.3845 (3.301 in.)	0.12700 (0.050 in.)	0.19812 (0.078 in.)	5.6347 (2.218 in.)	0.11430 (0.045 in.)
4	8.7097 (3.429 in.)	0.12700 (0.050 in.)	0.19812 (0.078 in.)	5.8901 (2.319 in.)	0.11430 (0.045 in.)
5	9.0348 (3.557 in.)	0.12700 (0.050 in.)	0.19812 (0.078 in.)	6.1455 (2.419 in.)	0.11430 (0.045 in.)
6	9.3599 (3.685 in.)	0.12700 (0.050 in.)	0.19812 (0.078 in.)	6.4009 (2.520 in.)	0.11430 (0.045 in.)
7	9.6850 (3.813 in.)	0.12700 (0.050 in.)	0.19812 (0.078 in.)	6.6563 (2.621 in.)	0.11430 (0.045 in.)
8	10.0101 (3.941 in.)	0.12700 (0.050 in.)	0.19812 (0.078 in.)	6.9116 (2.721 in.)	0.11430 (0.045 in.)
9	10.3353 (4.069 in.)	0.12700 (0.050 in.)	0.19812 (0.078 in.)	7.1670 (2.822 in.)	0.11430 (0.045 in.)
10	10.6604 (4.197 in.)	0.12700 (0.050 in.)	0.19558 (0.077 in.)	7.4224 (2.922 in.)	0.11430 (0.045 in.)
11	10.9830 (4.324 in.)	0.12700 (0.050 in.)	0.19558 (0.077 in.)	7.6757 (3.022 in.)	0.11430 (0.045 in.)
12	11.3055 (4.451 in.)	0.12700 (0.050 in.)	0.19558 (0.077 in.)	7.9291 (3.122 in.)	0.11430 (0.045 in.)
13	11.6281 (4.578 in.)	0.12700 (0.050 in.)	0.19558 (0.077 in.)	8.1825 (3.221 in.)	0.11430 (0.045 in.)
14	11.9507 (4.705 in.)	0.12700 (0.050 in.)	0.19558 (0.077 in.)	8.4358 (3.321 in.)	0.11430 (0.045 in.)
15	12.2733 (4.832 in.)	0.12700 (0.050 in.)	0.19558 (0.077 in.)	8.6892 (3.421 in.)	0.11430 (0.045 in.)
16	12.5959 (4.959 in.)	0.12700 (0.050 in.)	0.19558 (0.077 in.)	8.9426 (3.521 in.)	0.11430 (0.045 in.)
17	12.9184 (5.086 in.)	0.12700 (0.050 in.)	0.19558 (0.077 in.)	9.1959 (3.620 in.)	0.11430 (0.045 in.)
18	13.2410 (5.213 in.)	0.12700 (0.050 in.)	0.19558 (0.077 in.)	9.4493 (3.720 in.)	0.16510 (0.065 in.)
19	13.5636 (5.340 in.)	0.25400 (0.100 in.)	0.18542 (0.073 in.)	9.7027 (3.820 in.)	0.36830 (0.145 in.)

[a] According to (INEEL 2003 [DIRS 171506], p. 59), the inner radius of Plate 1 is 3.015 inches. All other radii are calculated from this value and the given thicknesses (*ATR.xls*, worksheet *Dimensions*).
[b] Data from (INEEL 2003 [DIRS 171506]).
[c] Calculated based on 45 degree fuel element, side plate thickness, and inner radii of fuel (see *ATR.xls*, worksheet *Dimensions*).

5.1.4.6 Fort St. Vrain Fuel and Canister Description

The MCNP input model representing Fort St. Vrain fuel in a canister utilized the existing MCNP input file can6 from the *Criticality Potential of Intact DOE SNF Canisters in a Misloaded Dry Waste Package* (BSC 2004 [DIRS 172201]) document as a starting point for the present calculations. The boundary conditions were the only changes made to the previously existing MCNP input files (see Section 5.2 for description of boundary conditions).

Fort St. Vrain (FSV) fuel consists of small particles of uranium carbide, which are coated with pyrolytic carbon and silicon carbide and then bound in a carbonized matrix to form a solid substance. This solid material is shaped into fuel compacts, which are then placed in channels drilled into large hexagonal prisms made of graphite. Each graphite block, loaded with fuel compacts, comprises one fuel element (Taylor, L.L. 2001 [DIRS 154726], Section 2.1.2). A radial view of a standard FSV fuel element is shown in Figure 5.1-7.

The FSV fuel elements are loaded into the DOE standardized SNF canister with no internal basket and no added neutron absorber. Each DOE standardized SNF canister can contain up to five FSV fuel elements, stacked axially. Dowels built into the fuel elements keep them aligned in the axial direction.

The geometry of the FSV fuel and SNF contents has been simplified to adapt the geometry to right prisms and cylinders (Assumption 3.2). A comparison of the actual dimensions with the dimensions used in the MCNP cases can be found in Table 5.1-6. The fuel composition is calculated in *SNF.xls*, worksheet *FSV*.

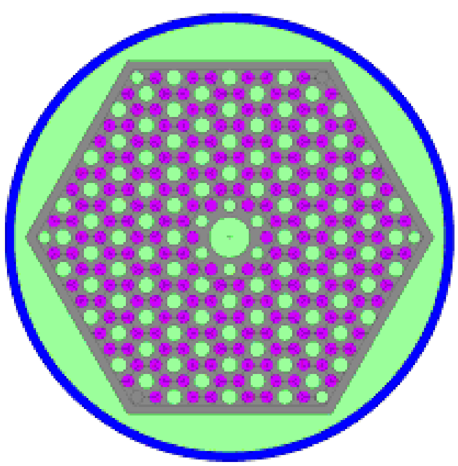


Figure 5.1-7 Radial View of Fort St. Vrain Canister

Table 5.1-6 Fort St. Vrain Fuel and Packaging Dimensions and Materials

Component	Material [a]	Parameter	Actual Dimension (mm) [a]	Dimension Used (mm)
Fuel Compact	Uranium or thorium carbide matrix	Outer Diameter	12.5	12.500
		Length	49.276	49.276
		Number per Fuel Channel	14 or 15	15
Fuel Channels	Void	Diameter	12.70	12.700
		Length [b]	~ 785.368	785.368
		Number	210	210
Top Plug for Fuel Channels	H-327 or H-451 graphite	Diameter	12.70	12.700
		Length	12.7	12.700
Void / Coolant Channels	Void	Diameter, innermost ring	12.700	12.700
		Diameter, standard	15.875	15.875
		Length	Not explicitly given	792.988
		Number	108	108
Burnable Poison Channels	Void [c]	Diameter	12.7	12.700
		Length	Not explicitly given	792.988
		Number	6	6
Central Fuel Handling Hole	Void	Diameter	41.275	41.275
		Length	381	381.000
Fuel Element	H-327 or H-451 graphite	Diameter (across flats)	360.60	360.600
		Length	792.988	792.988
		Channel Pitch	18.796	18.796
Long Standardized SNF Canister	SS 316L [d]	Inner Diameter	430 (min) [d]	438.150 [d]
		Inner Length	4114.8 (min) [d]	4117.000 [d]

[a] Source data from (Taylor, L.L. 2001 [DIRS 154726], Section 2.1.2), except where noted.
[b] The fuel channel length is the length of the non-plugged hole as measured from the top of the fuel element.
[c] No credit is taken for burnable poison; these channels are modeled as empty.
[d] Source data from Table 5.1-3.

5.1.4.7 FFTF Fuel and Canister Description

The MCNP input model representing FFTF fuel in a canister utilized the existing MCNP input file can2 from the *Criticality Potential of Intact DOE SNF Canisters in a Misloaded Dry Waste Package* (BSC 2004 [DIRS 172201]) document as a starting point for the present calculations. The boundary conditions were the only changes made to the previously existing MCNP input files (see Section 5.2 for description of boundary conditions).

There are four distinct types of FFTF standard driver fuel. The most reactive type (based on prior calculations) is the Type 4.1 driver fuel (CRWMS M&O 1999 [DIRS 102842], Sections 6.1.1 and 6.1.2). For this fuel type the fuel pin contains a mixed oxide fuel region of 70.72 wt% $UO_{1.96}$ and 29.28 wt% $PuO_{1.96}$ formed into dished pellets. Similar pellets made of natural UO_2 serve as an insulator at each end of the fuel region. On the outer ends of the UO_2 insulator regions are regions of Inconel 600 reflector. Above the top reflector is a spring made of SS 302 and a plenum of SS 316. The cladding and end caps are fabricated from SS 316 (INEEL 2002 [DIRS 158820], pp.15-17).

The FFTF standard driver fuel assembly (DFA) is hexagonally shaped and contains 217 cylindrical fuel pins as described above. Each fuel pin is held in place in a triangular-pitch array by a wire-wrapped spacer. The DFA also includes the inlet nozzle, orifice plates, neutron shield assembly, diffuser block, load pads, and handling socket (INEEL 2002 [DIRS 158820], Figure 3).

In addition to the whole DFAs, some standard and non-standard DFAs have been disassembled into fuel pins. These fuel pins range in diameter from 5.8 mm to 12.8 mm, and their compositions span a wide range of enrichments. The fuel pins from the disassembled DFAs are packaged into an Ident-69 container. Pins from different DFAs may be mixed in one container. The Ident-69 container with the highest Pu loading is Storage Serial No. ID69-033 (INEEL 2002 [DIRS 158820], Table A-2). The contents of this container are considered to be representative of the fuel type, and are chosen for use in this calculation. The 151 fuel pins stored in this container are 6.9 mm in diameter and had an initial enrichment of 31.2 wt% Pu/(Pu+U) with a surrounding insulator of depleted uranium oxide. For conservatism, this calculation replaces the depleted uranium oxide with natural uranium oxide.

The most reactive version of the Ident-69 container is the compartmented model (INEEL 2002 [DIRS 158820], p. 18), which can contain up to 217 fuel pins. The Ident-69 container is comprised of 5 in. SS 304L pipe with a transition to 2.5 in. pipe at one end of the container. Inside the pipe are a cylindrical central compartment and six radial compartments (BSC 2002 [DIRS 164418], Section 5.1.1). The fuel pins are contained within these compartments and supported on a grid plate. For this calculation, the Ident-69 canister internals are neglected (Assumption 3.3) and the fuel pins are conservatively modeled as a minimum-pitch hexagonal array in the center of the canister. The FFTF canister internals consist of basket with a cylindrical center tube and five divider plates extending radially from the center to the DOE standardized SNF canister inner wall (BSC 2002 [DIRS 164418], Sections 5.1.1 and 5.1.2).

This calculation considers an SNF basket made of Ni-Gd alloy and five DFAs loaded in the radial positions of the DOE standardized SNF canister. The geometry of the FFTF fuel and SNF contents has been simplified to adapt the geometry to right prisms and cylinders (Assumption 3.2). A comparison of the actual dimensions with the dimensions used in the MCNP cases can be found in Table 5.1-7. The FFTF fuel compositions are calculated in *SNF.xls*, worksheet *FFTF*.

Table 5.1-7 FFTF Fuel and Packaging Dimensions and Materials

Component	Material [a]	Parameter	Actual Dimension (mm) [a]	Dimension Used (mm)
FFTF Type 4.1 Driver Fuel Pins				
Fuel	70.72 wt% $UO_{1.96}$ and 29.28 wt% $PuO_{1.96}$	Outer Diameter	4.9403	4.9404
		Length	914.4	914.4000
Insulator	Natural UO_2	Outer Diameter	4.9403	4.9404
		Length, Top	20.32	20.3200
		Length, Bottom	20.32	20.3200
Reflector	Inconel 600	Outer Diameter	4.8133	4.9404
		Length, Top	144.78	144.7800
		Length, Bottom	144.78	144.7800
Spring	SS 302	Wire Diameter	0.8052	Neglected [d]
		Coiled Length	125.5	
Plenum	SS 316	Outer Diameter	4.9022	Neglected [d]
		Wall Thickness	0.1397	
		Length	862.1	
Cladding	SS 316	Inner Diameter	5.08	5.0800
		Outer Diameter	5.842	5.84520
		Thickness	0.381	0.3810
End Caps	SS 316	Outer Diameter	5.842	5.8420
		Length, Top	104.6	104.6000
		Length, Bottom	35.6	35.6000
Entire Fuel Pin	--------------	Length	2372.36	2372.3600
FFTF Type 4.1 Driver Fuel Assembly				
Fuel Pin Region	--------------	Length	2372.36	2372.3600
		Location (center of fuel)	1663.7 mm from bottom of DFA	1663.7 mm from bottom of DFA
		Pin Pitch	7.2644	7.2644
		Number of Pins	217	217
Wire-Wrapped Spacers	SS 316	Diameter	1.4224	Neglected [d]
		Axial Pitch	304.80	
Lower Assembly Region	--------------	Length	477.52 (calculated)	477.5200
		Diameter (across points)	138.1125 (max)	134.1810
Upper Assembly Region	--------------	Length	807.72 (calculated)	807.7200
		Diameter (across points)	138.1125 (max)	134.1810
Entire DFA	SS 316	Length	3657.6	3657.6000
		Diameter (across flats)	116.205	116.2050
		Diameter (across points)	131.064	134.1810 (calculated from diameter across flats)
		Wall Thickness	3.048	3.0480

Table 5.1-7 FFTF Fuel and Packaging Dimensions and Materials (cont.)

Component	Material [a]	Parameter	Actual Dimension (mm) [a]	Dimension Used (mm)
Fuel Pins in Ident-69 Container				
Fuel	68.8 wt% $UO_{1.96}$ and 31.2 wt% $PuO_{1.96}$	Outer Diameter	Not explicitly given	5.5558 [e,f]
		Length	Not explicitly given	914.4000 [e]
Insulator	Natural UO_2 [g]	Outer Diameter	Not explicitly given	5.5558 [e]
Reflector	Inconel 600	Outer Diameter	Not explicitly given	5.5558 [e]
Cladding	SS 316	Inner Diameter	Not explicitly given	6.1380 [e]
		Outer Diameter	6.9	6.9000
		Thickness	Not explicitly given	0.3810 [e]
End Caps	SS 316	Outer Diameter	Not explicitly given	6.9000 [e]
Remainder of Fuel Pin	------------	All other dimensions	Not explicitly given	Assumed same as Type 4.1 fuel [e]
Ident-69 Container				
Center Tube	Not explicitly given	Length	Not explicitly given	Neglected [d]
		Inner Diameter	41.402	
		Outer Diameter	44.450	
Divider Plates	Not explicitly given	Length	Not explicitly given	Neglected [d]
		Thickness	1.524 [b]	
Ident-69 Canister, Top Portion	SS 304L	Length	3225.8 [b]	3225.8000
		Inner Diameter	135.763	135.7630
		Outer Diameter	141.30	141.3000
Ident-69 Canister, Bottom Portion	SS 304L	Length	431.8	431.8000
		Inner Diameter	Not explicitly given	135.7630
		Outer Diameter	73.02	141.3000
Entire Ident-69 Canister	SS 304L	Inner Length	Not explicitly given	3652.0630
		Outer Length	3657.6	3657.6000
		Number of Pins	151	151
DOE Standardized SNF Canister				
Center Tube	Ni-Gd alloy [h]	Length	4125 [b]	4117.0000
		Inner Diameter	153 [b]	153.0000
		Outer Diameter	173 [b]	173.0000
Divider Plates	Ni-Gd alloy [h]	Length	4125 [b]	4117.0000
		Thickness	10 [b]	10.0000
Long Standardized SNF Canister	SS 316L [c]	Inner Diameter	430.0 (min) [c]	438.1500
		Inner Length	4114.8 (min) [c]	4117.0000

[a] Source data from INEEL 2002 [DIRS 158820], Section 3 unless stated otherwise.
[b] Source data from BSC 2002 [DIRS 164418], Section 5.1.1 and Section 5.1.2.
[c] Source data from Table 5.1-3.
[d] See Assumption 3.3. Spring region and plenum were represented as a void region 987.56 mm long.
[e] These fuel pins were assumed to be similar to Type 4.1 fuel pins (Assumption 3.5).
[f] Value calculated in *SNF.xls*, worksheet *FFTF*.
[g] Specified in INEEL 2002 [DIRS 158820], Table A-2 as depleted UO_2. Natural UO_2 was substituted.
[h] Specified in BSC 2002 [DIRS 164418], Section 5.1.2 as SS 316L doped with $GdPO_4$. Ni-Gd alloy was substituted.

5.1.4.8 Shippingport LWBR Fuel and Canister Description

As a starting point for the present Shippingport LWBR calculations, the existing MCNP input file sldds78 was utilized from the *Canister Handling Facility Criticality Safety Calculations* (BSC 2004 [DIRS 167614], which initially originated from the *Intact and Degraded Criticality Calculations for the Codisposal of Shippingport LWBR Spent Nuclear Fuel in a Waste Package* (CRWMS M&O 2000 [DIRS 151722]) document.

The fuel consists of a binary matrix of UO_2-ThO_2 (DOE 1999 [DIRS 105007], p. 16). The most reactive fuel consists of 5.202 wt% of U-233 and U-235 in the heavy metal and has a density of 9.71 g/cc (CRWMS M&O 2000 [DIRS 151722], Table 5-2). The fuel pellet OD is 0.252 inch (DOE 1999 [DIRS 105007], Table 3-5) or 0.64 cm and the pin pitch is 0.369 inch (DOE 1999 [DIRS 105007], Figure 3-3) or 0.937 cm. The cladding OD is 0.3063 inch and is 0.02217 inch thick (DOE 1999 [DIRS 105007], Table 3-8). There are 619 fuel rods per assembly (DOE 1999 [DIRS 105007], p. 16).

The DOE SNF canister is a right circular cylinder pipe made of stainless steel (Type 316L or UNS S31603) with an outside diameter of 457.2 mm (18 in.) and a wall thickness of 9.525 mm (0.375 in.). The nominal internal length of the DOE SNF canister reserved for fuel loading is 411.7086 cm (162.09 in.). The top and bottom carbon steel (ASME SA-36) impact plates are 50.8 mm (2.0 in.) thick at the centers (CRWMS M&O 2000 [DIRS 151722], p. 18). Dished heads seal the ends of the DOE SNF canister. The DOE SNF canister pipe extends several inches beyond the dished heads on each end to give a maximum external length of 456.9968 cm (179.92 in.). Each DOE SNF canister will also contain a rectangular basket structure to hold the Shippingport LWBR fuel assembly (CRWMS M&O 2000 [DIRS 151722], p. 18). The basket plates are made of 9.5 mm (0.374 in.) thick stainless steel (Type 316L or UNS S31603) and the inner widths of the plates are 295 mm and 257 mm, respectively. Finally, a boxed shaped spacer will fit inside the basket to elevate the SNF above the canister bottom (CRWMS M&O 2000 [DIRS 151722], p. 18).

5.1.4.9 TRIGA Fuel and Canister Description

The MCNP input model representing TRIGA fuel in a canister utilized the existing MCNP input file can7 from the *Criticality Potential of Intact DOE SNF Canisters in a Misloaded Dry Waste Package* (BSC 2004 [DIRS 172201]) document as a starting point for the present calculations. The boundary conditions were the only changes made to the previously existing MCNP input files (see Section 5.2 for description of boundary conditions).

For this calculation, the TRIGA fuel type FLIP in a standard-streamline stainless steel rod was used. This is the same fuel rod used in *TRIGA Fuel Phase I and II Criticality Calculation* (CRWMS M&O 1999 [DIRS 135852], Section 5.1.4).

TRIGA fuel is packaged as loose fuel elements held in place by support baskets. The FLIP fuel elements are made of uranium and zirconium hydride (approximately 91.5 wt% zirconium hydride (H/Zr ratio of 1.6) mixed with uranium of 70% U-235 enrichment). A hole is drilled through the center of the fuel, and a zirconium rod is inserted in the hole. The fuel and zirconium rod are contained in a SS 316 cladding. Graphite reflectors are present above and below the fuel inside the clad. Zirconium end fittings are swaged onto the ends of the fuel pin (DOE 1999 [DIRS 103891], Section 3.2).

The intact TRIGA fuel rods are placed into the DOE standardized SNF canister by first loading a base plate into the DOE standardized SNF canister, followed by a support basket. The support basket is made of SS 316L and holds 37 fuel pins, one per tube. Two more baskets are loaded into the DOE standardized SNF canister (with a base plate under each one) for a total of 111 fuel pins per DOE standardized SNF canister. No base plate is placed on top of the three layers (CRWMS M&O 1999 [DIRS 135852], Section 5.1.3 and Attachment IV). A radial view of the basket is shown in Figure 5.1-8.

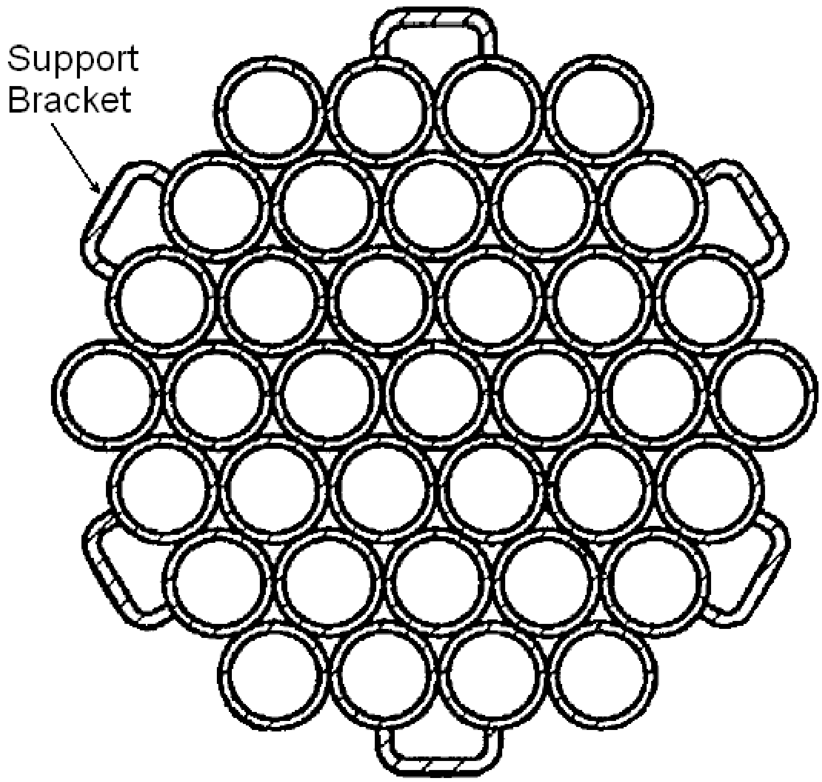


Figure 5.1-8 Basket Assembly for TRIGA SNF Canister

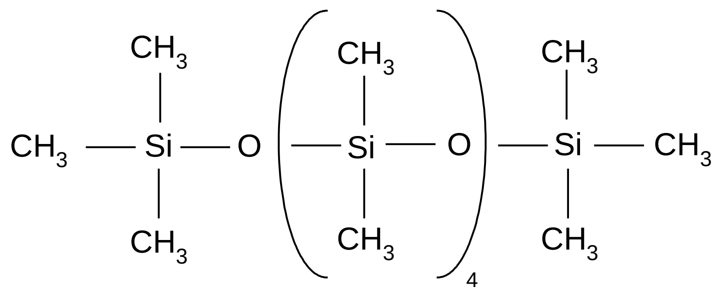
This calculation considers a support basket made of Ni-Gd alloy. The geometry of the TRIGA fuel and SNF contents has been simplified to adapt the geometry to right cylinders (Assumption 3.2). A comparison of the actual dimensions with the dimensions used in the MCNP cases can be found in Table 5.1-8. The TRIGA fuel composition is calculated in *SNF.xls*, worksheet *TRIGA*.

5.1-8 TRIGA Fuel and Packaging Dimensions and Materials

Component	Material [a]	Parameter	Actual Dimension (mm) [a]	Dimension Used (mm)
Zr Core	Zirconium	Outer Diameter	5.715	5.715
		Length	381.0	381.000
Fuel	U-$ZrH_{1.6}$	Inner Diameter	6.35	6.350
		Outer Diameter	36.449	36.449
		Length	381.0	381.000
Upper Reflector	Graphite	Outer Diameter	36.449	36.449
		Length	65.024	65.024
Lower Reflector	Graphite	Outer Diameter	36.449	36.449
		Length	94.488	94.488
Cladding	SS 304L	Inner Diameter	36.525	36.525
		Outer Diameter	37.541	37.541
		Inner Length	Not given	540.512
		Outer Length	753.872	600.512 [b]
Support Basket (each tube)	SS 316L [c]	Inner Diameter	49.3 [d]	49.300
		Outer Diameter	60.3 [d]	60.300
		Length	836 [d]	836.000
		Pitch	60.3 [d]	60.300
Basket Support Bracket	SS 316L	Thickness	7.9 [d]	Neglected [e]
		Length	150 [d]	Neglected [e]
Base Plate	SS 316L	Diameter	426 [d]	438.150 [f]
		Thickness	9.5 [d]	9.500
Void over Top Layer	Void	Length	10.5 [d]	38.500 [g]
Short Standardized SNF Canister	SS 316L [h]	Inner Diameter	430 (min)[h]	438.150
		Inner Length	2540 (min) [h]	2575.000

[a] Source data from DOE 1999 [DIRS 103891], Section 3.2 and Section 3.2.1, except where noted.
[b] The end fittings were modeled as a right circular cylinder with the same volume and mass as the end plugs, and an adjacent region of void for the remainder of the fuel pin length (see Assumption 3.2).
[c] Specified in CRWMS M&O 1999 [DIRS 135852], Section 5.2 as SS 316L with a coating of advanced absorber matrix. Ni-Gd alloy with no additional absorber was substituted.
[d] Source data from CRWMS M&O 1999 [DIRS 135852], Attachment IV.
[e] See Assumption 3.3.
[f] Diameter increased to simplify modeling.
[g] Length of void increased to match short DOE standardized SNF canister interior length.
[h] Taken from Table 5.1-2

Per Assumption 3.4, Polysiloxane fluid was chosen as an alternate moderator material (in the event hydraulic fluid/oil leak from a handling crane). The chemical formula for this fluid is



Source: (Gelest 2004 [DIRS 169915], p. 11)

Polysiloxane fluid was modeled with a density of 0.9 g/cm^3 (Gelest 2004 [DIRS 169915], p. 11).

5.2 CRITICALITY CALCULATIONS

5.2.1 Dry Single DOE Canisters

MCNP calculations were performed for the various DOE fuel types (see Section 5.1.2) modeled as single canisters. The canisters are modeled as dry, since they will remain sealed during handling in the CHF (see Section 1). The impact of no poison loading present in the basket structure (due to manufacturer errors, etc.) was also investigated for the applicable DOE SNF canisters. The results are presented in Section 6.1.

5.2.2 Dry Arrays of DOE Canisters

The DOE SNF canisters were modeled in an array configuration to investigate a minimum separation distance for the staging racks in the CHF. In order to find the most reactive configuration in the CHF, various potential outside reflector materials were evaluated. The reflector materials considered are void/air and water. Previous studies have shown that higher k_{eff} is produced with canister surrounded by air than concrete for DOE fuel in canisters when canister separation is equal to or less than 60 cm for array of canisters (there are some exceptions at 60 cm distance) (BSC 2004 [DIRS 171589], Table 5.2-1). Consequently concrete was not considered as a reflector material. The reflector is modeled with a 30 cm width/height in the radial and axial directions. An infinite array of casks was also evaluated to investigate neutronic isolation. The results are presented in Section 6.2.

5.2.3 Category 1 and 2 Event Sequences

The Category 1 and Category 2 event sequences applicable to the CHF have been identified in the *Categorization of Event Sequences for License Application* document (BSC 2004 [DIRS 167268], Section 7). Only Category 2 events have been identified for the CHF and are presented in Table 5.2-1. The supporting calculations for the event sequences are provided in Section 6.3. They included rearranged fuel and moderator (water) flooded canisters for defense in depth. Also, hydraulic fluid/oil was also considered as a moderator (because it may leak from a handling crane) for defense in depth.

Table 5.2-1 Category 2 Event Sequences for CHF

Event Sequence identifier	Criticality Event Description	Reference
2-01	Drop of a transportation cask without impact limiters in the CHF	BSC 2004 [DIRS 167268], Section 7
2-03	Drop of inner lid of a transportation cask, MSC, or WP into a transportation cask, MSC, or WP in the CHF	
2-07	Drop of a canister during transfer by crane	
2-08	Drop of handling equipment onto a canister	
2-10	Drop of unsealed WP in CHF	
2-11	Drop of a WP with a known closure defect	
2-24	Drop or collision of handling equipment into an open WP loaded with DOE canisters	

6. RESULTS AND CONCLUSIONS

This section presents the results of the criticality calculations and makes recommendations for additional criticality safety design features as appropriate. The outputs presented in this document are all reasonable compared to the inputs and the results are suitable for the intended use. The uncertainties are taken into account by consistently using a conservative approach, which is the result of the methods and assumptions described in Sections 2 and 3, respectively.

6.1 SINGLE DOE CANSITERS

Table 6.1-1 presents the k_{eff} values along with their standard deviation (St. Dev.) of the various DOE fuel types with and without fixed neutron poison present. For the scenarios without fixed neutron absorber present (for defense in depth to account for manufacturer errors, etc.), the basket structures were replaced by void in the MCNP model. It can be seen from Table 6.1-1 that the neutron poison in a dry environment has an insignificant effect on the reactivity of the DOE SNF canisters. The changes in k_{eff} are due to the presence or absence of additional material in the canister. Overall, all of the k_{eff} values are much below the USL and poses no criticality concerns.

Table 6.1-1 k_{eff} Values of Dry Single Canisters With and Without Poison

DOE Fuel	With neutron poison			Without neutron poison		
	k_{eff}	St. Dev.	MCNP files	k_{eff}	St. Dev.	MCNP files
FFTF	0.31462	0.00029	fftf5sG, fftf5sG.out	0.29702	0.00030	fftf5sG0, fftf5sG0.out
Fermi	0.32351	0.00032	fermi-s, fermi-s.out	0.26127	0.00024	fermi-s0, fermi-s0.out
Triga	0.38785	0.00075	triga-s, triga-s.out	0.40668	0.00083	triga-s0, triga-s0.out
Fort St. Vrain	N/A	N/A	N/A	0.03191	0.00018	fsv-s0, fsv-s0.out
TMI	N/A	N/A	N/A	0.21680	0.00031	tmi-k0, tmi-k0.out & tmi-k0.out1
ATR	0.02170	0.00003	atr-s, atr-s.out	0.02010	0.00002	atr-s0, atr-s0.out
Shippingport PWR	N/A	N/A	N/A	0.04193	0.00005	sh-ps0, sh-ps0.out
Shippingport LWBR	N/A	N/A	N/A	0.11399	0.00013	sh-ls0, sh-ls0.out
N-Reactor (Mark 1A)	N/A	N/A	N/A	0.23368	0.00028	nr1A-s0, nr1A-s0.out
N-Reactor (Mark IV)	N/A	N/A	N/A	0.28555	0.00032	nr4B-s0, nr4B-s0.out

6.2 ARRAYS OF DOE CANISTERS

Table 6.2-1 presents the k_{eff} values of an infinite (x and y directions) array of dry DOE SNF canisters surrounded by air. The canisters are either almost touching (0.001 cm separation) or are placed 30 cm apart. It can be seen that FFTF, Fermi, and TRIGA fuel types exceed the USL when they are almost touching. Consequently, the DOE fuel canisters must be placed 30 cm apart in the CHF staging racks to remain below USL. There are no limitations to the array size. Also note that these calculations do not take credit for the fixed neutron absorbers, except where noted. As mentioned in Section 6.1, the neutron absorber contribution in a dry environment is insignificant as demonstrated in Table 6.1-1.

The same array configurations were also investigated with water as an outside reflector. The results are presented in Table 6.2-2 and it can be seen that water presence outside the canister reduces the reactivity of the canister array.

Table 6.2-1 k_{eff} Values of Dry Canisters in an Infinite Array W/o Poison (Air Surrounding Canisters)

DOE Fuel	0.001 cm separation between canisters			30 cm separation between canisters		
	keff	St. Dev.	MCNP files	keff	St. Dev.	MCNP files
FFTF	1.10418	0.00069	fftf5a0A, fftf5a0A.out	0.58884	0.00053	fft30a0A, fft30a0A.out
	1.06506 [a]	0.00066	fftP5a0A, fftP5a0A.out			
Fermi	1.05684	0.00064	fermiAa0, fermiAa0.out	0.54998	0.00046	fer30a0A, fer30a0A.out
	0.97844 [a]	0.00052	fermPAa0, fermPAa0.out			
Triga	1.23663	0.00090	trigaAa0, trigaAa0.out	0.83546	0.00104	tri30a0A, tri30a0A.out
	0.68213 [a]	0.00076	trigPAa0, trigPAa0.out			
Fort St. Vrain	0.72281	0.00063	fsvAa0, fsvAa0.out	0.36730	0.00060	fsv30Aa0, fsv30Aa0.out
TMI	0.35692	0.00040	tmiKAa0, tmiKAa0.out	0.26954	0.00033	tmi30Aa0, tmi30Aa0.out
ATR	0.43270	0.00054	atrAa0, atrAa0.out	0.07974	0.00012	atr30Aa0, atr30Aa0.out
Shippingport PWR	0.50674	0.00046	shPAa0, shPAa0.out	0.13513	0.00018	shP30Aa0, shP30Aa0.out
Shippingport LWBR	0.43852	0.00038	shLAa0, shLAa0.out	0.22163	0.00024	shL30Aa0, shL30Aa0.out
N-Reactor (Mark 1A)	0.38492	0.00033	nr1AaA0, nr1AaA0.out	0.32870	0.00033	nr1A30a0, nr1A30a0.out
N-Reactor (Mark IV)	0.40684	0.00041	nr4BaA0, nr4BaA0.out	0.36811	0.00036	nr4B30aA, nr4B30aA.out

[a] Calculated as designed with the neutron poison present.

Table 6.2-2 keff Values of Dry Canisters in an Infinite Array W/o Poison (Water Surrounding Canisters)

DOE Fuel	0.001 cm separation between canisters			30 cm separation between canisters		
	keff	St. Dev.	MCNP files	keff	St. Dev.	MCNP files
FFTF	0.75006	0.00074	fftf5a0, fftf5a0.out	0.48338	0.00061	fft30a0, fft30a0.out
	0.66975 [a]	0.00067	fftfP5a0, fftfP5a0.out			
Fermi	0.78956	0.00073	fermi-a0, fermi-a0.out	0.49676	0.00068	ferm30a0, ferm30a0.out
	0.50959 [a]	0.00050	fermiPa0, fermiPa0.out			
Triga	0.82504	0.00096	triga-a0, triga-a0.out	0.58690	0.00090	trig30a0, trig30a0.out
	0.49261 [a]	0.00071	trigaPa0, trigaPa0.out			
Fort St. Vrain	0.37636	0.00059	fsv-a0, fsv-a0.out	0.19520	0.00047	fsv30a0, fsv30a0.out
TMI	0.26660	0.00038	tmiK-a0, tmiK-a0.out	0.23468	0.00034	tmiK30a0, tmiK30a0.out
ATR	0.36625	0.00060	atr-a0, atr-a0.out	0.17875	0.00042	atr30a0, atr30a0.out
Shippingport PWR	0.24891	0.00050	shP-a0, shP-a0.out	0.13348	0.00039	shP30a0, shP30a0.out
Shippingport LWBR	0.32144	0.00057	shL-a0, shL-a0.out	0.20036	0.00044	shL30a0, shL30a0.out
N-Reactor (Mark 1A)	0.42652	0.00044	nr1A-a0, nr1A-a0.out	0.33741	0.00040	nr1A30aA, nr1A30aA.out
N-Reactor (Mark IV)	0.45035	0.00048	nr4B-a0, nr4B-a0.out	0.37214	0.00046	nr4B30a0, nr4B30a0.out

[a] Calculated as designed with the neutron poison present.

6.3 CATEGORY 1 AND 2 EVENT SEQUENCES

Table 6.3-1 presents the evaluation of the Category 1 and 2 event sequences for the CHF. As mentioned in Section 5.2.3, only Category 2 events have been identified for the CHF.

Table 6.3-1 Evaluation of Category 2 Event Sequences for CHF

Event Sequence identifier [a]	Criticality Event Description	Criticality Safety Evaluation
2-01	Drop of a transportation cask without impact limiters.	Per Assumption 3.1, the DOE canisters will not breach due a drop and, consequently, a moderator cannot intrude into the canister to make the system more reactive. Also, see supporting defense in depth calculations below.
2-03	Drop of inner lid of a transportation cask, MSC, or WP into a transportation cask, MSC, or WP.	Table 6.3-2 presents the results of rearranged DOE fuel inside of the canisters and this scenario does not pose any criticality concerns. Defense in depth evaluations have also been performed below for when moderators are present.
2-07	Drop of a canister during transfer by crane.	See evaluation for event sequence 2-01
2-08	Drop of handling equipment onto a canister.	See evaluation for event sequence 2-03
2-10	Drop of unsealed WP.	See evaluation for event sequence 2-01
2-11	Drop of a WP with a known closure defect.	See evaluation for event sequence 2-01
2-24	Drop or collision of handling equipment into an open WP loaded with DOE canisters	See evaluation for event sequence 2-03

[a] BSC 2004 [DIRS 167268], Section 7

Loss of geometric structure, due to a drop, inside the canister was studied for the most reactive DOE SNF under dry conditions without any fixed poison present. Since the DOE canisters will remain unopened, the dry conditions represent undamaged canister containment. Further, single canisters were considered since it is not credible that two or more canisters would be dropped near each other due to that movement of canisters is limited to one canister at a time (BSC 2004 [DIRS 168992], p. 2-3). Table 6.3-2 presents the calculated k_{eff} values for the DOE fuel types considered. The results show that a loss of geometric structure (e.g., broken/lost support tubes) inside the DOE canisters under dry conditions does not pose a criticality concern.

Table 6.3-2 keff Values of Single Dry Canisters W/o Poison and Geometric Structure (Air Surrounding Canisters)

DOE Fuel	Dry Single Canisters		
	k_{eff}	St. Dev.	MCNP files
FFTF	0.31558	0.00031	fftf5sGr, fftf5sGr.out
Fermi	0.27196	0.00028	fermiGs0, fermiGs0.out
TRIGA	0.49726	0.00097	trigaGs0, trigaGs0.out
Fort St. Vrain	0.07931	0.00031	fsvGs0, fsvGs0.out
TMI	0.27964	0.00031	tmi-s, tmi-s.out

For defense-in-depth, flooded conditions are considered for TRIGA fuel (most reactive fuel based on the scenarios described above) in the event the drop will puncture the canister containment and water is present in the facility. Table 6.3-3 presents the k_{eff} values as a function of water height. Hydraulic fluid/oil was also considered as a potential moderator in case it may leak from a handling crane. The results show that the moderator height, for defense in depth, should be controlled to 55 cm from the bottom of the canisters in order to be within the USL. Note that these conclusions are based on non-credit for neutron poison, which is very conservative. Table 6.3-3 shows that a fully flooded TRIGA canister with neutron poison present is well below USL. It can also be seen from Table 6.3-3 that the neutron poison is very effective in a wet environment. Note that the limiting moderator height could vary for other DOE SNF canisters.

Table 6.3-3 keff Values of Flooded TRIGA Canister W/o Poison and Geometric Structure (Air Surrounding Canister)

Moderator (water) height (cm)	TRIGA fuel		
	k_{eff}	St. Dev.	MCNP files
192 [a]	1.13643	0.00095	trigGs0w, trigGs0w.out
192 [a, b]	0.55482	0.00085	triPGs0w, triPGs0w.out
192 [a, b] (oil)	0.51105	0.00084	triPGs0o, triPGs0o.out
128	1.13199	0.00100	triGs0w1, triGs0w1.out
64	1.01983	0.00110	triGs0w4, triGs0w4.out
60	0.97158	0.00109	triGs0w7, triGs0w7.out
55	0.87970	0.00104	triGs0w6, triGs0w6.out
55 (oil)	0.82499	0.00113	triGs0o6, triGs0o6.out
50	0.74743	0.00106	triGs0w5, triGs0w5.out

[a] Fully flooded
[b] Calculated with neutron poison present

6.4 CONCLUSIONS AND RECOMMENDATIONS

The processes for the CHF have been evaluated for criticality safety for normal operations, Category 1 and 2 event sequences. The results presented in this document lead to the following conclusions and recommendations:

- All of the nine DOE SNF types considered (see Section 5.1.2) are safely below USL as single canisters under dry normal operations.

- When the DOE SNF canisters are placed in a dry infinite array configuration, the canisters needs to be separated by 30 cm (canister surface to canister surface) to safely be below USL.

- The identified evaluated Category 2 events for the CHF were found criticality safe under nominal conditions.

- For defense in depth:

1. an infinite array of DOE SNF canisters placed 30 cm apart without neutron absorber (to account for manufacturer errors, etc.) under dry conditions is criticality safe.
2. a fully flooded single canister (TRIGA fuel) with neutron absorber is criticality safe.
3. an infinite array of DOE SNF canisters with dry inside and wet outside is criticality safe (with and without neutron absorber).

In summary, normal operations in CHF prove to be criticality safe for all DOE SNF types considered in this calculation. The DOE SNF canisters can be placed in an infinite array size as long as the spacing between the surfaces of the canisters is 30 cm or greater. A fully flooded scenario does not pose a criticality concern when taking credit for the neutron poison. Consequently, the moderator controlled areas of the CHF, shown in Attachment III, are provided for defense in depth. It should also be mentioned that design requirements, as indicated by Assumption 3.1, need to be implemented to limit lift heights in the CHF to ensure no breaching of DOE SNF canisters. Further, it will be required when selecting the design basis hydraulic fluid (Assumption 3.4) that it is a less effective moderator than water.

7. REFERENCES

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8. ATTACHMENTS

This calculation document includes three attachments:

ATTACHMENT I	Listing of Computer Files
ATTACHMENT II	One Compact Disc
ATTACHMENT III	Canister Handling Facility General Arrangement Drawings (Secondary references on these drawings are not relevant to this calculation.)

ATTACHMENT I
LISTING OF COMPUTER FILES

All MCNP input and output files documented in this calculation were stored on an electronic medium (compact disc) as Attachment II. Also, the Microsoft® Excel spreadsheets used to calculate input values are included on the compact disc.

Date	Time	Size	File
02/25/2005	02:24p	52,736	ATR.xls
02/25/2005	01:48p	57,344	SNF.xls
02/15/2005	09:04a	20,308	DRY-S/atr-s
02/15/2005	09:04a	686,365	DRY-S/atr-s.out
02/15/2005	09:04a	20,244	DRY-S/atr-s0
02/15/2005	09:04a	664,459	DRY-S/atr-s0.out
02/15/2005	09:04a	16,297	DRY-S/fermi-s
02/15/2005	09:04a	1,919,921	DRY-S/fermi-s.out
02/15/2005	09:04a	16,077	DRY-S/fermi-s0
02/15/2005	09:05a	1,881,146	DRY-S/fermi-s0.out
02/15/2005	09:05a	20,403	DRY-S/fftf5sG
02/15/2005	09:05a	1,737,079	DRY-S/fftf5sG.out
02/15/2005	09:05a	20,355	DRY-S/fftf5sG0
02/15/2005	09:05a	1,721,262	DRY-S/fftf5sG0.out
02/15/2005	09:05a	16,372	DRY-S/fsv-s0
02/15/2005	09:05a	505,463	DRY-S/fsv-s0.out
02/15/2005	09:04a	7,963	DRY-S/nr1A-s0
02/15/2005	09:04a	419,758	DRY-S/nr1A-s0.out
02/15/2005	09:04a	7,868	DRY-S/nr4B-s0
02/15/2005	09:04a	432,630	DRY-S/nr4B-s0.out
02/15/2005	09:04a	12,214	DRY-S/sh-ls0
02/15/2005	09:04a	489,045	DRY-S/sh-ls0.out
02/15/2005	09:04a	28,313	DRY-S/sh-ps0
02/15/2005	09:04a	774,170	DRY-S/sh-ps0.out
02/15/2005	09:04a	53,739	DRY-S/tmi-ko
02/15/2005	09:04a	815,141	DRY-S/tmi-ko.out
02/15/2005	09:04a	594,545	DRY-S/tmi-ko.out1
02/15/2005	09:05a	11,068	DRY-S/triga-s
02/15/2005	09:05a	599,801	DRY-S/triga-s.out
02/15/2005	09:05a	11,036	DRY-S/triga-s0
02/15/2005	09:05a	594,868	DRY-S/triga-s0.out
02/15/2005	09:04a	15,985	DRY-S/GEOM/fermiGs0
02/15/2005	09:04a	1,880,828	DRY-S/GEOM/fermiGs0.out
02/15/2005	09:04a	20,610	DRY-S/GEOM/fftf5sGr
02/15/2005	09:04a	1,724,202	DRY-S/GEOM/fftf5sGr.out
02/15/2005	09:04a	16,373	DRY-S/GEOM/fsvGs0
02/15/2005	09:04a	507,079	DRY-S/GEOM/fsvGs0.out
02/15/2005	09:04a	11,106	DRY-S/GEOM/tmi-s
02/15/2005	09:04a	452,854	DRY-S/GEOM/tmi-s.out
02/15/2005	09:04a	11,051	DRY-S/GEOM/trigaGs0

Date	Time	Size	File
02/15/2005	09:04a	682,577	DRY-S/GEOM/trigaGs0.out
02/25/2005	02:51p	11,080	DRY-S/GEOM/MOD/trigGs0w
02/25/2005	02:51p	686,672	DRY-S/GEOM/MOD/trigGs0w.out
02/25/2005	02:51p	13,170	DRY-S/GEOM/MOD/triGs0o6
02/25/2005	02:51p	777,979	DRY-S/GEOM/MOD/triGs0o6.out
02/25/2005	02:51p	13,098	DRY-S/GEOM/MOD/triGs0w1
02/25/2005	02:51p	702,087	DRY-S/GEOM/MOD/triGs0w1.out
02/25/2005	02:51p	13,188	DRY-S/GEOM/MOD/triGs0w4
02/25/2005	02:51p	775,771	DRY-S/GEOM/MOD/triGs0w4.out
02/25/2005	02:51p	13,188	DRY-S/GEOM/MOD/triGs0w5
02/25/2005	02:51p	775,877	DRY-S/GEOM/MOD/triGs0w5.out
02/25/2005	02:51p	13,188	DRY-S/GEOM/MOD/triGs0w6
02/25/2005	02:51p	775,877	DRY-S/GEOM/MOD/triGs0w6.out
02/25/2005	02:51p	13,188	DRY-S/GEOM/MOD/triGs0w7
02/25/2005	02:51p	775,994	DRY-S/GEOM/MOD/triGs0w7.out
03/10/2005	02:17p	11,091	DRY-S/GEOM/MOD/triPGs0o
03/10/2005	02:17p	694,233	DRY-S/GEOM/MOD/triPGs0o.out
03/10/2005	02:17p	11,112	DRY-S/GEOM/MOD/triPGs0w
03/10/2005	02:17p	691,884	DRY-S/GEOM/MOD/triPGs0w.out
02/15/2005	09:00a	20,614	DRY-A/atr-a0
02/15/2005	09:00a	668,961	DRY-A/atr-a0.out
02/15/2005	09:00a	20,638	DRY-A/atr30a0
02/15/2005	09:00a	669,441	DRY-A/atr30a0.out
02/15/2005	09:00a	20,634	DRY-A/atr30Aa0
02/15/2005	09:00a	668,407	DRY-A/atr30Aa0.out
02/15/2005	09:00a	20,610	DRY-A/atrAa0
02/15/2005	09:00a	677,119	DRY-A/atrAa0.out
02/15/2005	09:00a	16,370	DRY-A/fer30a0A
02/15/2005	09:00a	1,883,608	DRY-A/fer30a0A.out
02/15/2005	09:00a	16,339	DRY-A/ferm30a0
02/15/2005	09:00a	1,885,159	DRY-A/ferm30a0.out
02/15/2005	09:00a	16,309	DRY-A/fermi-a0
02/15/2005	09:00a	1,884,841	DRY-A/fermi-a0.out
02/15/2005	09:00a	16,980	DRY-A/fermiAa
02/15/2005	09:00a	1,924,381	DRY-A/fermiAa.out
02/15/2005	09:00a	16,352	DRY-A/fermiAa0
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02/15/2005	09:01a	20,391	DRY-A/fft30a0A
02/15/2005	09:01a	1,724,765	DRY-A/fft30a0A.out
02/15/2005	09:01a	20,344	DRY-A/fftf30a0
02/15/2005	09:01a	1,723,611	DRY-A/fftf30a0.out
02/15/2005	09:01a	20,346	DRY-A/fftf5a0
02/15/2005	09:01a	1,726,109	DRY-A/fftf5a0.out
02/15/2005	09:01a	20,393	DRY-A/fftf5a0A
02/15/2005	09:01a	1,736,809	DRY-A/fftf5a0A.out
02/15/2005	09:01a	16,607	DRY-A/fsv-a0
02/15/2005	09:01a	512,014	DRY-A/fsv-a0.out

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02/15/2005	09:01a	16,603	DRY-A/fsvAa0
02/15/2005	09:01a	514,605	DRY-A/fsvAa0.out
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02/15/2005	09:01a	423,518	DRY-A/nr1A-a0.out
03/21/2005	04:24p	8,328	DRY-A/nr1A30a0
03/21/2005	04:24p	423,360	DRY-A/nr1A30a0.out
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02/15/2005	09:01a	424,466	DRY-A/nr1A30aA.out
02/15/2005	09:01a	8,345	DRY-A/nr1AaA0
02/15/2005	09:01a	423,996	DRY-A/nr1AaA0.out
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02/15/2005	09:01a	438,298	DRY-A/nr4B-a0.out
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02/15/2005	09:01a	435,556	DRY-A/nr4B30a0.out
02/15/2005	09:01a	8,231	DRY-A/nr4B30aA
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02/15/2005	09:01a	28,712	DRY-A/shP30a0
02/15/2005	09:01a	779,502	DRY-A/shP30a0.out
02/15/2005	09:01a	28,706	DRY-A/shP30Aa0
02/15/2005	09:01a	779,097	DRY-A/shP30Aa0.out
02/15/2005	09:01a	28,683	DRY-A/shPAa0
02/15/2005	09:01a	780,995	DRY-A/shPAa0.out
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02/15/2005	09:02a	1,051,621	DRY-A/ tmiK-a0.out
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Date	Time	Size	File
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02/15/2005	09:02a	598,691	DRY-A/triga-a0.out
02/15/2005	09:02a	11,267	DRY-A/trigaAa0
02/15/2005	09:02a	596,873	DRY-A/trigaAa0.out
03/10/2005	02:19p	16,537	DRY-A/fermiPa0
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03/10/2005	02:19p	1,741,395	DRY-A/fftfP5a0.out
03/10/2005	02:19p	20,623	DRY-A/fftP5a0A
03/10/2005	02:19p	1,751,257	DRY-A/fftP5a0A.out
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02/15/2005	09:01a	28,712	DRY-A/shP30a0
02/15/2005	09:01a	779,502	DRY-A/shP30a0.out
02/15/2005	09:01a	28,706	DRY-A/shP30Aa0
02/15/2005	09:01a	779,097	DRY-A/shP30Aa0.out
02/15/2005	09:01a	28,683	DRY-A/shPAa0
02/15/2005	09:01a	780,995	DRY-A/shPAa0.out
03/10/2005	02:20p	11,302	DRY-A/trigaPa0
03/10/2005	02:20p	602,648	DRY-A/trigaPa0.out
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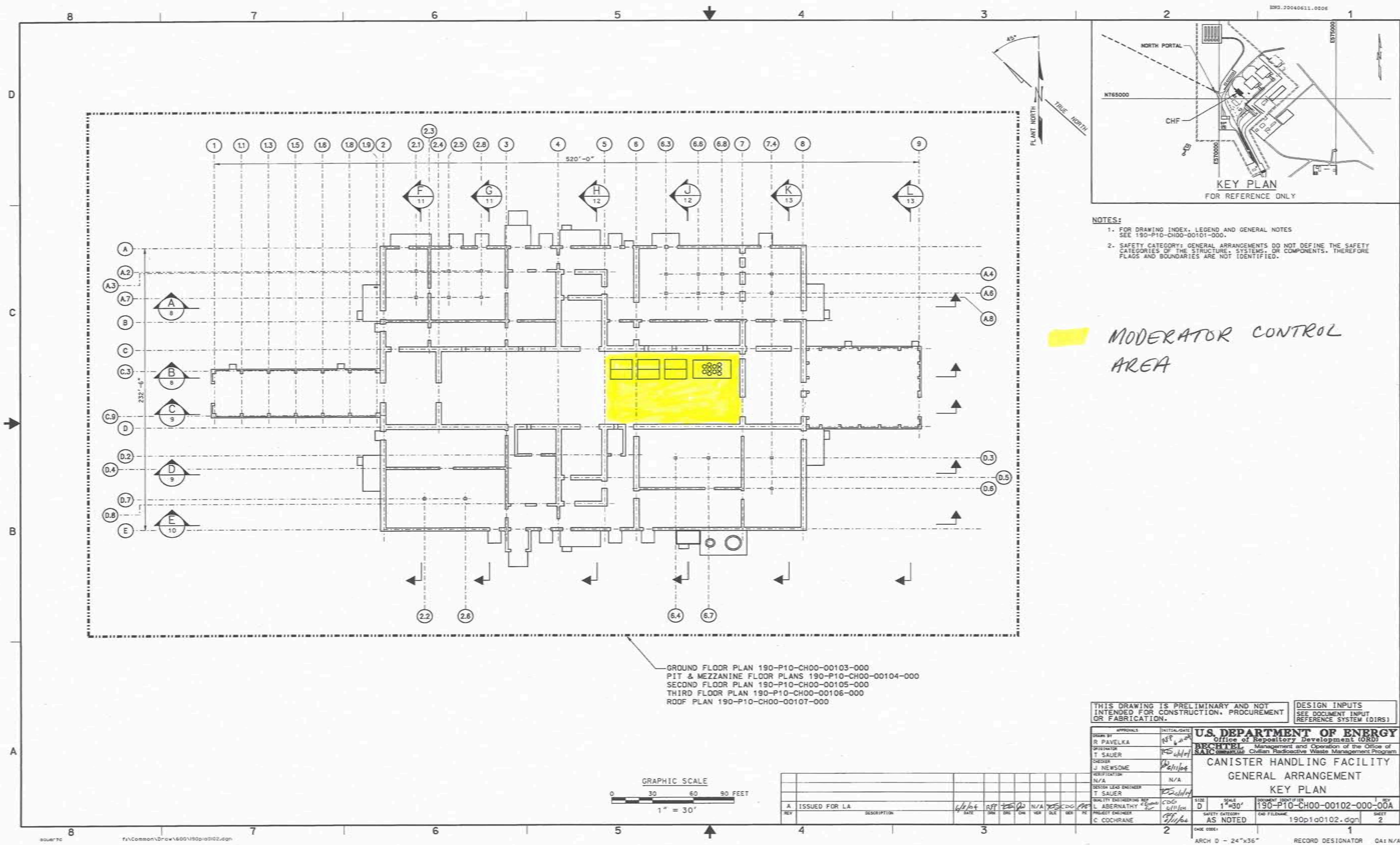
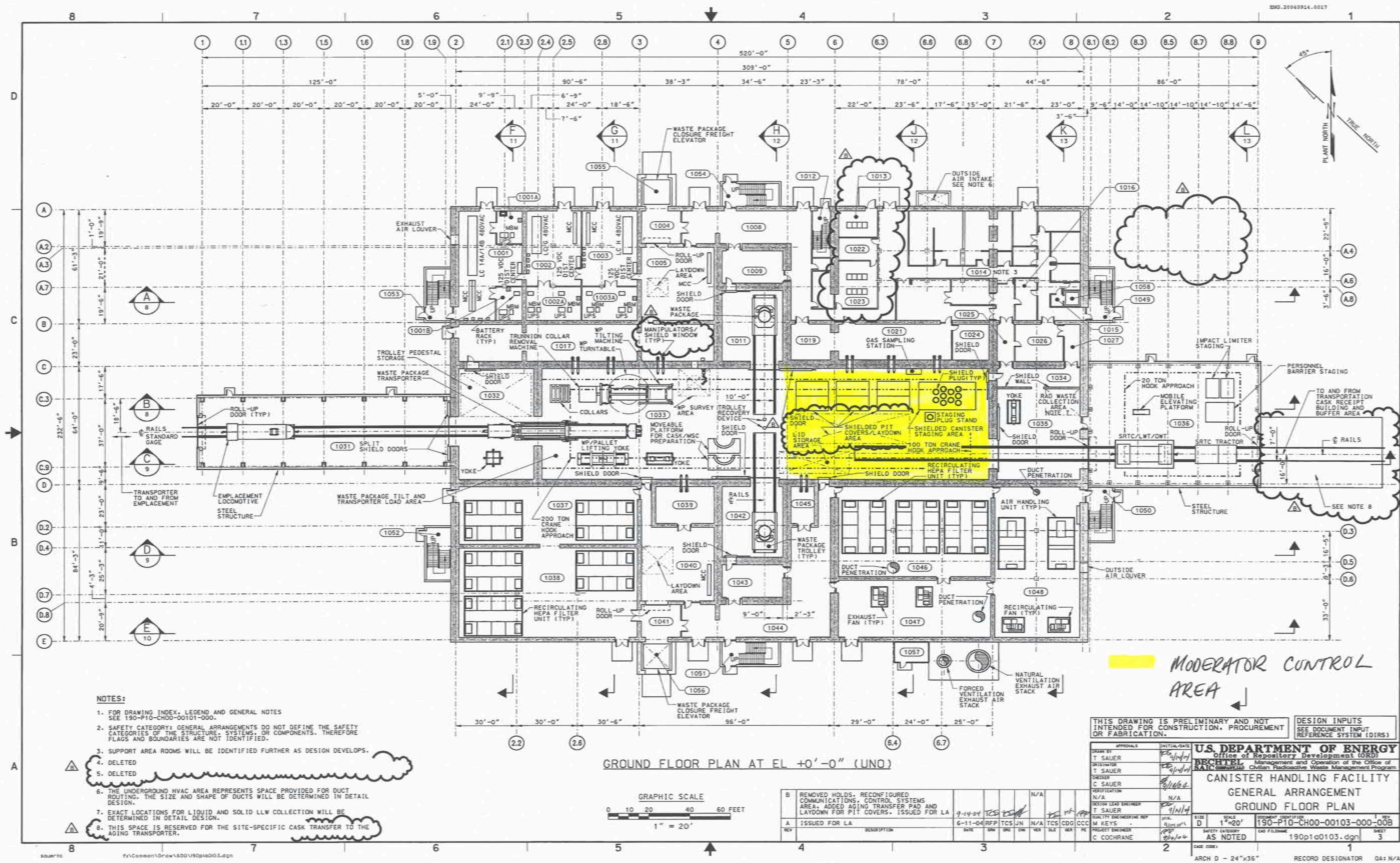
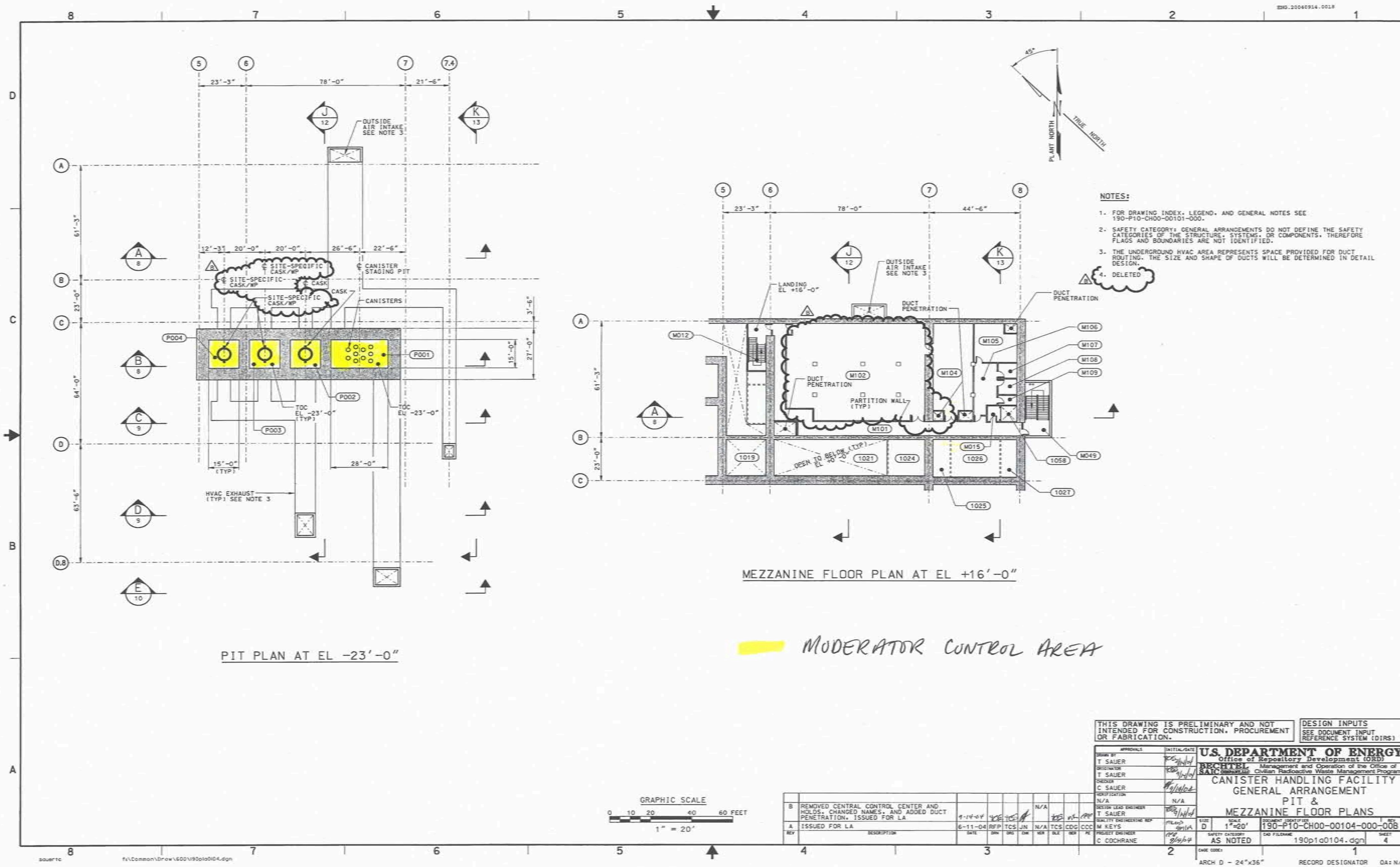
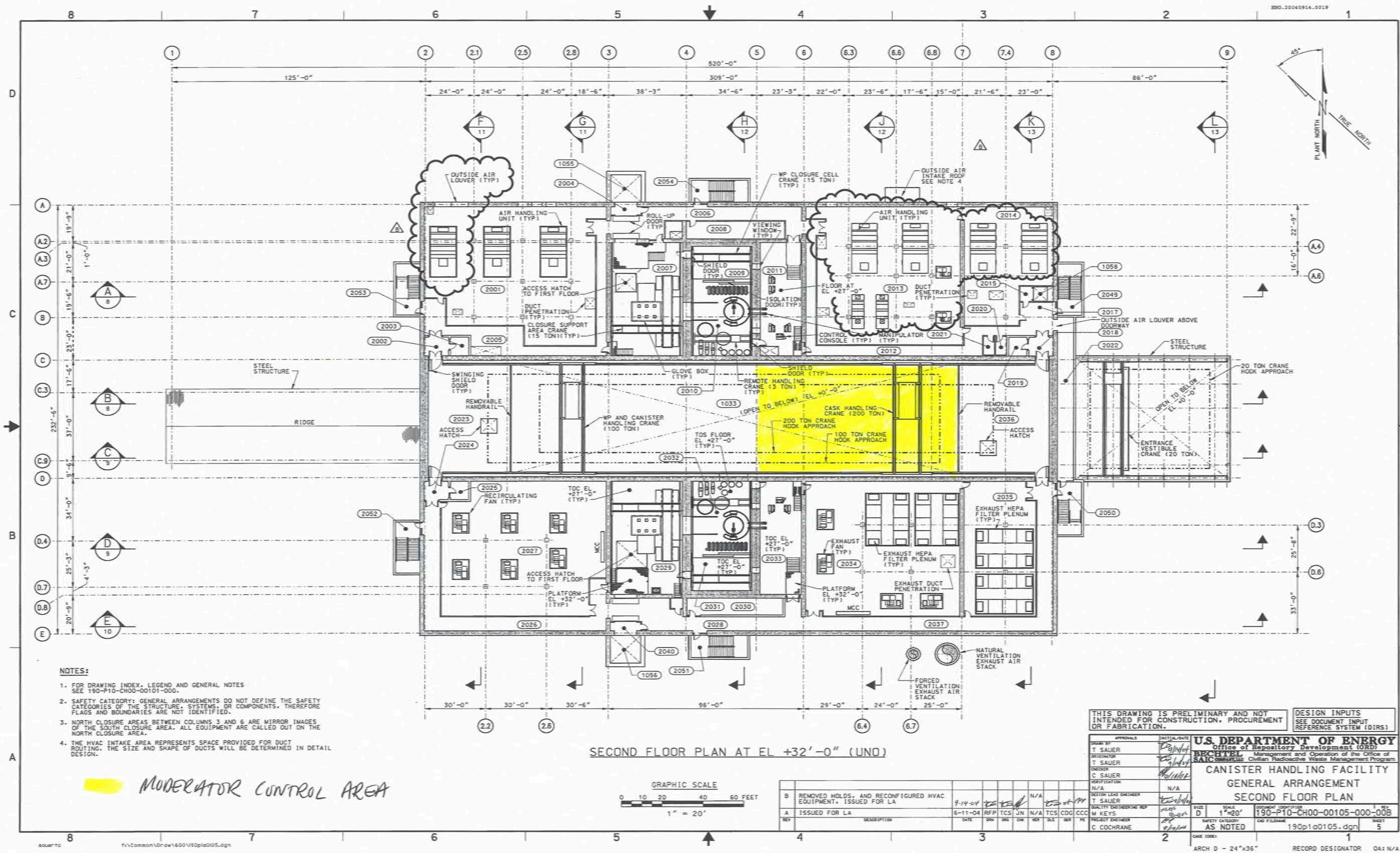
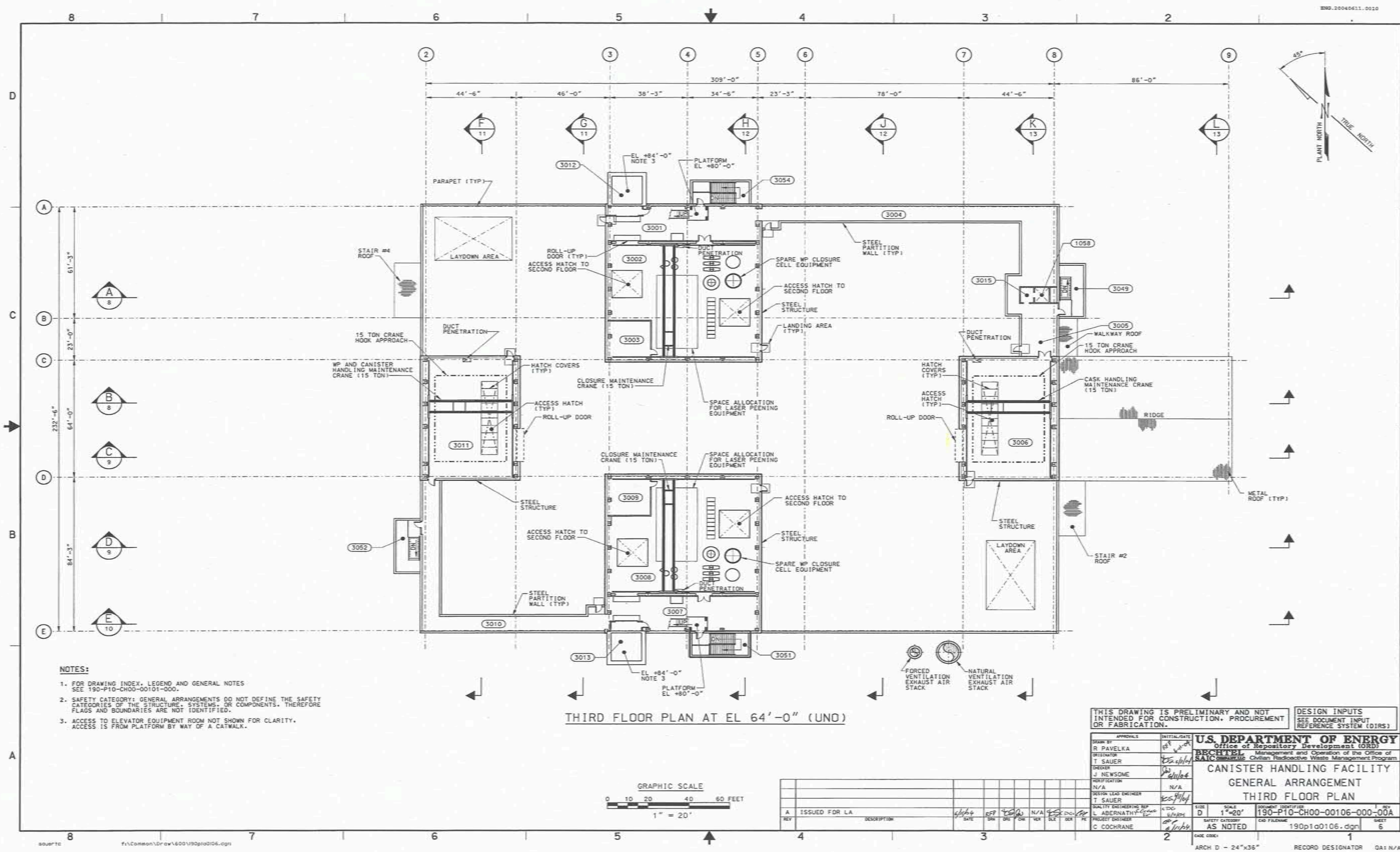


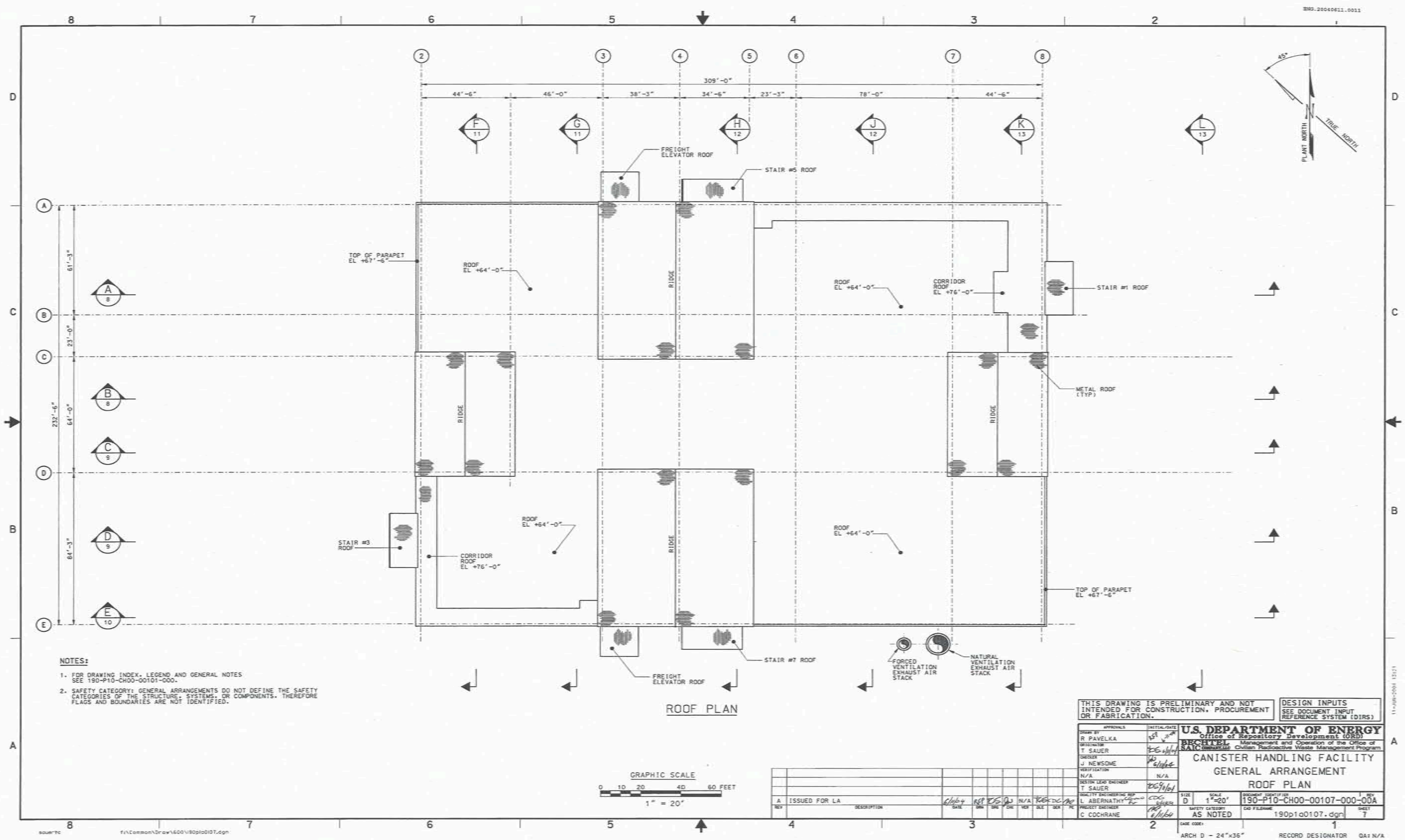
MODERATOR CONTROL AREA
NORTH PORTAL
N765000
CHF
E570000
E575000
KEY PLAN
FOR REFERENCE ONLY
PLANT NORTH
TRUE NORTH
45°
520'-0"
232'-6"
NOTES:
1. FOR DRAWING INDEX, LEGEND AND GENERAL NOTES SEE 190-P10-CH00-00101-000.
2. SAFETY CATEGORY: GENERAL ARRANGEMENTS DO NOT DEFINE THE SAFETY CATEGORIES OF THE STRUCTURE, SYSTEMS, OR COMPONENTS. THEREFORE FLAGS AND BOUNDARIES ARE NOT IDENTIFIED.
GROUND FLOOR PLAN 190-P10-CH00-00103-000
PIT & MEZZANINE FLOOR PLANS 190-P10-CH00-00104-000
SECOND FLOOR PLAN 190-P10-CH00-00105-000
THIRD FLOOR PLAN 190-P10-CH00-00106-000
ROOF PLAN 190-P10-CH00-00107-000
GRAPHIC SCALE
0 30 60 90 FEET
1" = 30'
THIS DRAWING IS PRELIMINARY AND NOT INTENDED FOR CONSTRUCTION, PROCUREMENT OR FABRICATION.
DESIGN INPUTS
SEE DOCUMENT INPUT REFERENCE SYSTEM (DIRS)
A ISSUED FOR LA
U.S. DEPARTMENT OF ENERGY
Office of Repository Development (ORD)
BECHTEL SAIC COMPANY LLC Management and Operation of the Office of Civilian Radioactive Waste Management Program
DRAWN BY R PAVELKA
ORIGINATOR T SAUER
CHECKER J NEWSOME
VERIFICATION N/A N/A
DESIGN LEAD ENGINEER T SAUER
QUALITY ENGINEERING REP L ABERNATHY
PROJECT ENGINEER C COCHRANE
CANISTER HANDLING FACILITY
GENERAL ARRANGEMENT
KEY PLAN
SIZE D
SCALE 1"=30'
DOCUMENT IDENTIFIER 190-P10-CH00-00102-000-00A
SAFETY CATEGORY AS NOTED
CAD FILENAME 190p1o0102.dgn
SHEET 2
ARCH D - 24"x36"
RECORD DESIGNATOR
QA: N/A

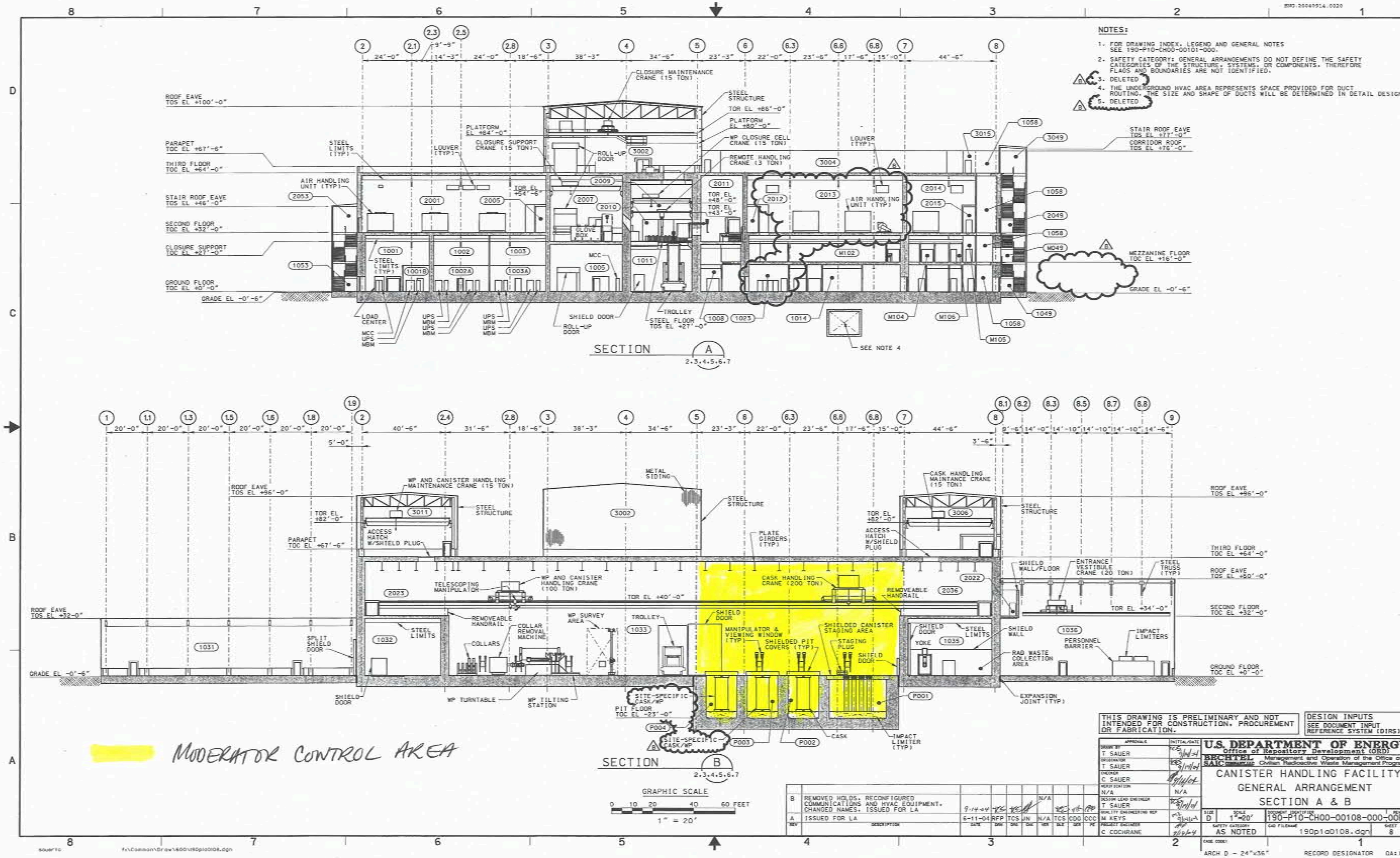

GROUND FLOOR PLAN AT EL +0'-0" (UNO)
MODERATOR CONTROL AREA
NOTES:
1. FOR DRAWING INDEX, LEGEND AND GENERAL NOTES SEE 190-P10-CH00-00101-000.
2. SAFETY CATEGORY: GENERAL ARRANGEMENTS DO NOT DEFINE THE SAFETY CATEGORIES OF THE STRUCTURE, SYSTEMS, OR COMPONENTS. THEREFORE FLAGS AND BOUNDARIES ARE NOT IDENTIFIED.
3. SUPPORT AREA ROOMS WILL BE IDENTIFIED FURTHER AS DESIGN DEVELOPS.
4. DELETED
5. DELETED
6. THE UNDERGROUND HVAC AREA REPRESENTS SPACE PROVIDED FOR DUCT ROUTING. THE SIZE AND SHAPE OF DUCTS WILL BE DETERMINED IN DETAIL DESIGN.
7. EXACT LOCATIONS FOR LIQUID AND SOLID LLW COLLECTION WILL BE DETERMINED IN DETAIL DESIGN.
8. THIS SPACE IS RESERVED FOR THE SITE-SPECIFIC CASK TRANSFER TO THE AGING TRANSPORTER.
GRAPHIC SCALE
1" = 20'
THIS DRAWING IS PRELIMINARY AND NOT INTENDED FOR CONSTRUCTION, PROCUREMENT OR FABRICATION.
DESIGN INPUTS
SEE DOCUMENT INPUT REFERENCE SYSTEM (DIRS)
U.S. DEPARTMENT OF ENERGY
Office of Repository Development (ORD)
BECHTEL SAIC Management and Operation of the Office of Civilian Radioactive Waste Management Program
CANISTER HANDLING FACILITY
GENERAL ARRANGEMENT
GROUND FLOOR PLAN
DRAWN BY T SAUER
ORIGINATOR T SAUER
CHECKER C SAUER
VERIFICATION N/A
DESIGN LEAD ENGINEER T SAUER
QUALITY ENGINEERING REP M KEYS
PROJECT ENGINEER C COCHRANE
SIZE D
SCALE 1"=20'
DOCUMENT IDENTIFIER 190-P10-CH00-00103-000-00B
SAFETY CATEGORY AS NOTED
CAD FILENAME 190p1o0103.dgn
SHEET 3
ARCH D - 24"x36"
RECORD DESIGNATOR
QA: N/A
B REMOVED HOLDS, RECONFIGURED COMMUNICATIONS, CONTROL SYSTEMS AREA, ADDED AGING TRANSFER PAD AND LAYDOWN FOR PIT COVERS. ISSUED FOR LA
A ISSUED FOR LA
SHIELDED PIT COVERS/LAYDOWN AREA
SHIELDED CANISTER STAGING AREA
LID STORAGE AREA
STAGING PLUG STAND
SHIELD PLUG (TYP)
100 TON CRANE HOOK APPROACH
RECIRCULATING HEPA FILTER UNIT (TYP)
SHIELD DOOR


PIT PLAN AT EL -23'-0"
MEZZANINE FLOOR PLAN AT EL +16'-0"
MODERATOR CONTROL AREA
NOTES:
1. FOR DRAWING INDEX, LEGEND, AND GENERAL NOTES SEE 190-P10-CH00-00101-000.
2. SAFETY CATEGORY: GENERAL ARRANGEMENTS DO NOT DEFINE THE SAFETY CATEGORIES OF THE STRUCTURE, SYSTEMS, OR COMPONENTS. THEREFORE FLAGS AND BOUNDARIES ARE NOT IDENTIFIED.
3. THE UNDERGROUND HVAC AREA REPRESENTS SPACE PROVIDED FOR DUCT ROUTING. THE SIZE AND SHAPE OF DUCTS WILL BE DETERMINED IN DETAIL DESIGN.
4. DELETED
THIS DRAWING IS PRELIMINARY AND NOT INTENDED FOR CONSTRUCTION, PROCUREMENT OR FABRICATION.
U.S. DEPARTMENT OF ENERGY
CANISTER HANDLING FACILITY GENERAL ARRANGEMENT PIT & MEZZANINE FLOOR PLANS
190-P10-CH00-00104-000-00B
B REMOVED CENTRAL CONTROL CENTER AND HOLDS, CHANGED NAMES, AND ADDED DUCT PENETRATION. ISSUED FOR LA
A ISSUED FOR LA
GRAPHIC SCALE 1" = 20'


SECOND FLOOR PLAN AT EL +32'-0" (UNO)
NOTES:
1. FOR DRAWING INDEX, LEGEND AND GENERAL NOTES SEE 190-P10-CH00-00101-000.
2. SAFETY CATEGORY: GENERAL ARRANGEMENTS DO NOT DEFINE THE SAFETY CATEGORIES OF THE STRUCTURE, SYSTEMS, OR COMPONENTS. THEREFORE FLAGS AND BOUNDARIES ARE NOT IDENTIFIED.
3. NORTH CLOSURE AREAS BETWEEN COLUMNS 3 AND 6 ARE MIRROR IMAGES OF THE SOUTH CLOSURE AREA. ALL EQUIPMENT ARE CALLED OUT ON THE NORTH CLOSURE AREA.
4. THE HVAC INTAKE AREA REPRESENTS SPACE PROVIDED FOR DUCT ROUTING. THE SIZE AND SHAPE OF DUCTS WILL BE DETERMINED IN DETAIL DESIGN.
MODERATOR CONTROL AREA
GRAPHIC SCALE
1" = 20'
CASK HANDLING CRANE (200 TON)
200 TON CRANE HOOK APPROACH
100 TON CRANE HOOK APPROACH
WP AND CANISTER HANDLING CRANE (100 TON)
THIS DRAWING IS PRELIMINARY AND NOT INTENDED FOR CONSTRUCTION, PROCUREMENT OR FABRICATION.
DESIGN INPUTS
SEE DOCUMENT INPUT REFERENCE SYSTEM (DIRS)
U.S. DEPARTMENT OF ENERGY
Office of Repository Development (ORD)
BECHTEL SAIC Management and Operation of the Office of Civilian Radioactive Waste Management Program
CANISTER HANDLING FACILITY
GENERAL ARRANGEMENT
SECOND FLOOR PLAN
B REMOVED HOLDS, AND RECONFIGURED HVAC EQUIPMENT, ISSUED FOR LA 9-14-04
A ISSUED FOR LA 6-11-04 RFP TCS JN N/A TCS CDG CCC
DRAWN BY T SAUER
ORIGINATOR T SAUER
CHECKER C SAUER
VERIFICATION N/A
DESIGN LEAD ENGINEER T SAUER
QUALITY ENGINEERING REP M KEYS
PROJECT ENGINEER C COCHRANE
SIZE D SCALE 1"=20'
DOCUMENT IDENTIFIER 190-P10-CH00-00105-000-00B
SAFETY CATEGORY AS NOTED
CAD FILENAME 190p1o0105.dgn
SHEET 5
ARCH D - 24"x36"
RECORD DESIGNATOR QA: N/A


THIRD FLOOR PLAN AT EL 64'-0" (UNO)
NOTES:
1. FOR DRAWING INDEX, LEGEND AND GENERAL NOTES SEE 190-P10-CH00-00101-000.
2. SAFETY CATEGORY: GENERAL ARRANGEMENTS DO NOT DEFINE THE SAFETY CATEGORIES OF THE STRUCTURE, SYSTEMS, OR COMPONENTS. THEREFORE FLAGS AND BOUNDARIES ARE NOT IDENTIFIED.
3. ACCESS TO ELEVATOR EQUIPMENT ROOM NOT SHOWN FOR CLARITY. ACCESS IS FROM PLATFORM BY WAY OF A CATWALK.
GRAPHIC SCALE
0 10 20 40 60 FEET
1" = 20'
309'-0"
44'-6"
46'-0"
38'-3"
34'-6"
23'-3"
78'-0"
44'-6"
86'-0"
232'-6"
61'-3"
23'-0"
64'-0"
84'-3"
PLANT NORTH
TRUE NORTH
45°
PARAPET (TYP)
LAYDOWN AREA
STAIR #4 ROOF
STAIR #2 ROOF
ROLL-UP DOOR (TYP)
ACCESS HATCH TO SECOND FLOOR
DUCT PENETRATION
SPARE WP CLOSURE CELL EQUIPMENT
STEEL STRUCTURE
STEEL PARTITION WALL (TYP)
LANDING AREA (TYP)
15 TON CRANE HOOK APPROACH
WP AND CANISTER HANDLING MAINTENANCE CRANE (15 TON)
HATCH COVERS (TYP)
ACCESS HATCH (TYP)
ROLL-UP DOOR
CLOSURE MAINTENANCE CRANE (15 TON)
SPACE ALLOCATION FOR LASER PEENING EQUIPMENT
CASK HANDLING MAINTENANCE CRANE (15 TON)
WALKWAY ROOF
RIDGE
METAL ROOF (TYP)
EL +84'-0" NOTE 3
PLATFORM EL +80'-0"
FORCED VENTILATION EXHAUST AIR STACK
NATURAL VENTILATION EXHAUST AIR STACK
3001
3002
3003
3004
3005
3006
3007
3008
3009
3010
3011
3012
3013
3015
3049
3051
3052
3054
1058
A ISSUED FOR LA
THIS DRAWING IS PRELIMINARY AND NOT INTENDED FOR CONSTRUCTION, PROCUREMENT OR FABRICATION.
DESIGN INPUTS
SEE DOCUMENT INPUT REFERENCE SYSTEM (DIRS)
APPROVALS
DRAWN BY R PAVELKA
ORIGINATOR T SAUER
CHECKER J NEWSOME
VERIFICATION N/A
DESIGN LEAD ENGINEER T SAUER
QUALITY ENGINEERING REP L ABERNATHY
PROJECT ENGINEER C COCHRANE
U.S. DEPARTMENT OF ENERGY
Office of Repository Development (ORD)
BECHTEL SAIC COMPANY, LLC
Management and Operation of the Office of Civilian Radioactive Waste Management Program
CANISTER HANDLING FACILITY
GENERAL ARRANGEMENT
THIRD FLOOR PLAN
SIZE D
SCALE 1"=20'
DOCUMENT IDENTIFIER 190-P10-CH00-00106-000-00A
SAFETY CATEGORY AS NOTED
CAD FILENAME 190p1a0106.dgn
SHEET 6
ARCH D - 24"x36"
RECORD DESIGNATOR
QA: N/A


309'-0"
44'-6"
46'-0"
38'-3"
34'-6"
23'-3"
78'-0"
44'-6"
FREIGHT ELEVATOR ROOF
STAIR #5 ROOF
TOP OF PARAPET EL +67'-6"
ROOF EL +64'-0"
RIDGE
CORRIDOR ROOF EL +76'-0"
STAIR #1 ROOF
METAL ROOF (TYP)
STAIR #3 ROOF
STAIR #7 ROOF
FORCED VENTILATION EXHAUST AIR STACK
NATURAL VENTILATION EXHAUST AIR STACK
PLANT NORTH
TRUE NORTH
45°
61'-3"
23'-0"
232'-6"
64'-0"
64'-3"
NOTES:
1. FOR DRAWING INDEX, LEGEND AND GENERAL NOTES SEE 190-P10-CH00-00101-000.
2. SAFETY CATEGORY: GENERAL ARRANGEMENTS DO NOT DEFINE THE SAFETY CATEGORIES OF THE STRUCTURE, SYSTEMS, OR COMPONENTS. THEREFORE FLAGS AND BOUNDARIES ARE NOT IDENTIFIED.
ROOF PLAN
GRAPHIC SCALE
0 10 20 40 60 FEET
1" = 20'
THIS DRAWING IS PRELIMINARY AND NOT INTENDED FOR CONSTRUCTION, PROCUREMENT OR FABRICATION.
DESIGN INPUTS
SEE DOCUMENT INPUT REFERENCE SYSTEM (DIRS)
U.S. DEPARTMENT OF ENERGY
Office of Repository Development (ORD)
BECHTEL SAIC
Management and Operation of the Office of Civilian Radioactive Waste Management Program
CANISTER HANDLING FACILITY
GENERAL ARRANGEMENT
ROOF PLAN
R PAVELKA
T SAUER
J NEWSOME
N/A
T SAUER
L ABERNATHY
C COCHRANE
A ISSUED FOR LA
D 1"=20'
190-P10-CH00-00107-000-00A
AS NOTED
190p1o0107.dgn
ARCH D - 24"x36"
RECORD DESIGNATOR
QA: N/A


NOTES:
1. FOR DRAWING INDEX, LEGEND AND GENERAL NOTES SEE 190-P10-CH00-00101-000.
2. SAFETY CATEGORY: GENERAL ARRANGEMENTS DO NOT DEFINE THE SAFETY CATEGORIES OF THE STRUCTURE, SYSTEMS, OR COMPONENTS. THEREFORE FLAGS AND BOUNDARIES ARE NOT IDENTIFIED.
3. DELETED
4. THE UNDERGROUND HVAC AREA REPRESENTS SPACE PROVIDED FOR DUCT ROUTING. THE SIZE AND SHAPE OF DUCTS WILL BE DETERMINED IN DETAIL DESIGN.
5. DELETED
SECTION A
SECTION B
CASK HANDLING CRANE (200 TON)
SHIELDED CANISTER STAGING AREA
MANIPULATOR & VIEWING WINDOW (TYP)
SHIELDED PIT COVERS (TYP)
STAGING PLUG
SHIELD DOOR
CASK
IMPACT LIMITER (TYP)
PIT FLOOR TOC EL -23'-0"
SITE-SPECIFIC CASK/MP
MODERATOR CONTROL AREA
GRAPHIC SCALE
1" = 20'
THIS DRAWING IS PRELIMINARY AND NOT INTENDED FOR CONSTRUCTION, PROCUREMENT OR FABRICATION.
DESIGN INPUTS
SEE DOCUMENT INPUT REFERENCE SYSTEM (DIRS)
B REMOVED HOLDS, RECONFIGURED COMMUNICATIONS AND HVAC EQUIPMENT, CHANGED NAMES, ISSUED FOR LA 9-14-04
A ISSUED FOR LA 6-11-04 RFP TCS JN N/A TCS CDG CCC
DRAWN BY T SAUER
ORIGINATOR T SAUER
CHECKER C SAUER
VERIFICATION N/A
DESIGN LEAD ENGINEER T SAUER
QUALITY ENGINEERING REP M KEYS
PROJECT ENGINEER C COCHRANE
U.S. DEPARTMENT OF ENERGY
Office of Repository Development (ORD)
BECHTEL SAIC Management and Operation of the Office of Civilian Radioactive Waste Management Program
CANISTER HANDLING FACILITY
GENERAL ARRANGEMENT
SECTION A & B
SIZE D SCALE 1"=20'
190-P10-CH00-00108-000-00B
SAFETY CATEGORY AS NOTED
CAD FILENAME 190p1o0108.dgn
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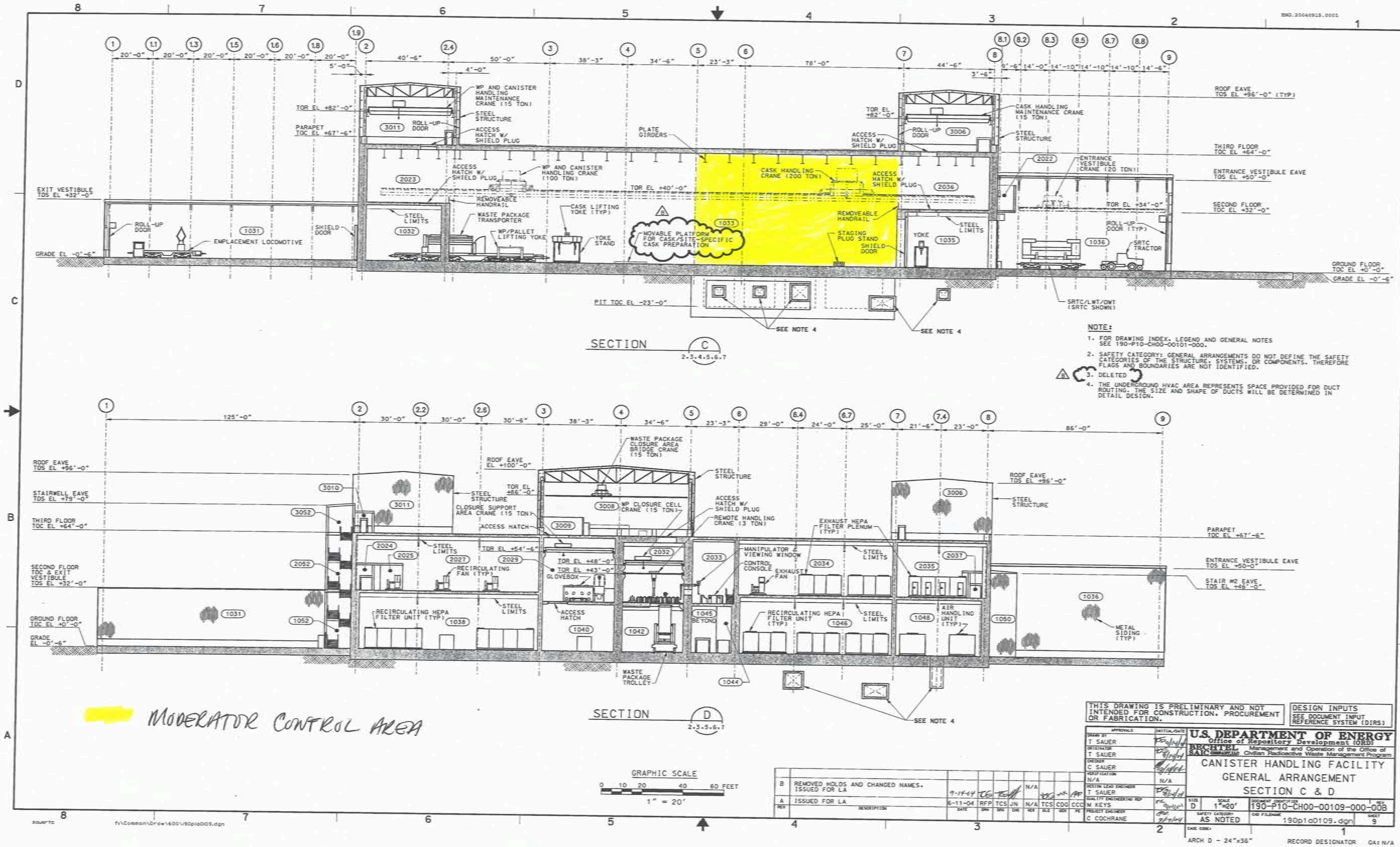
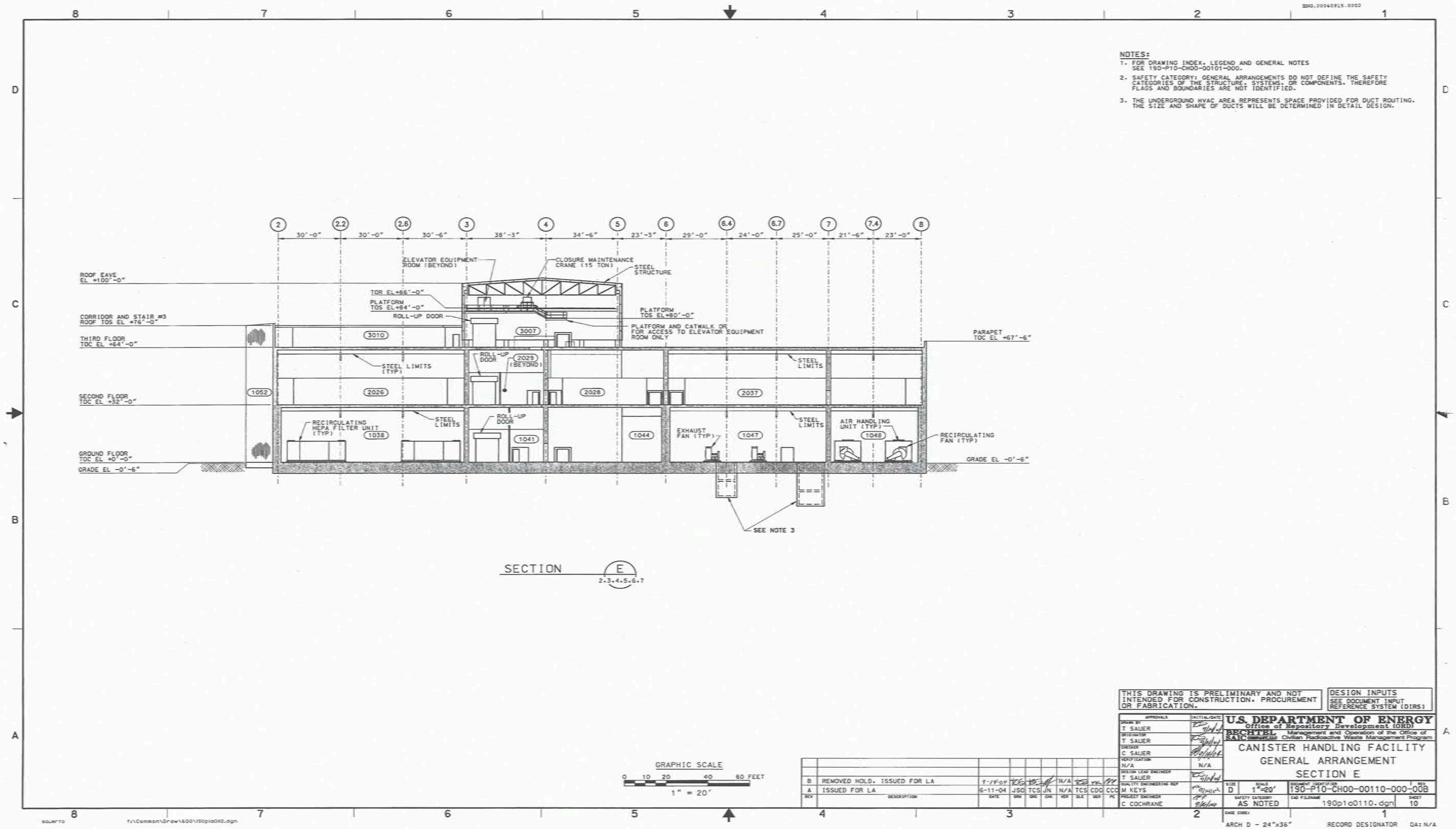
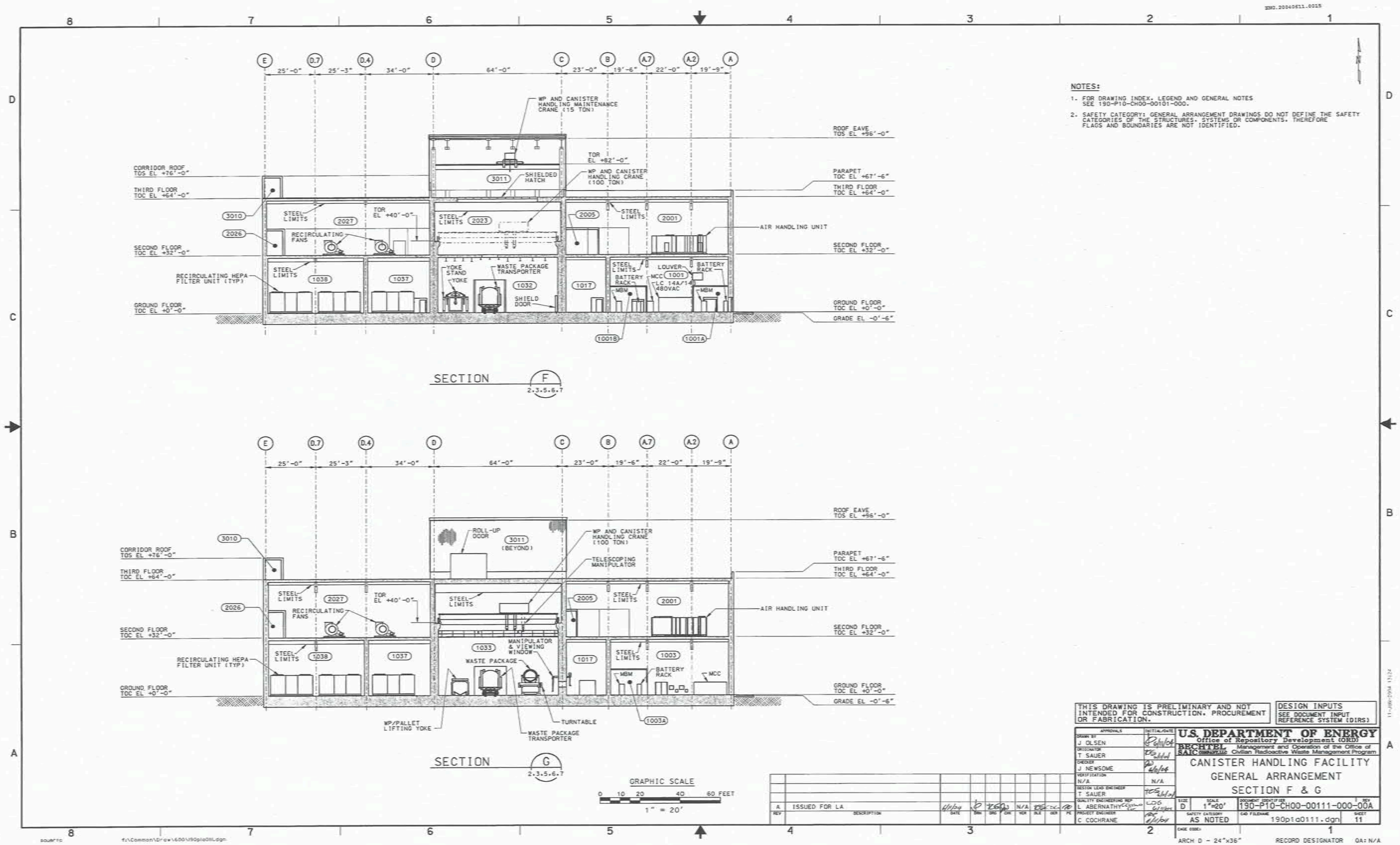
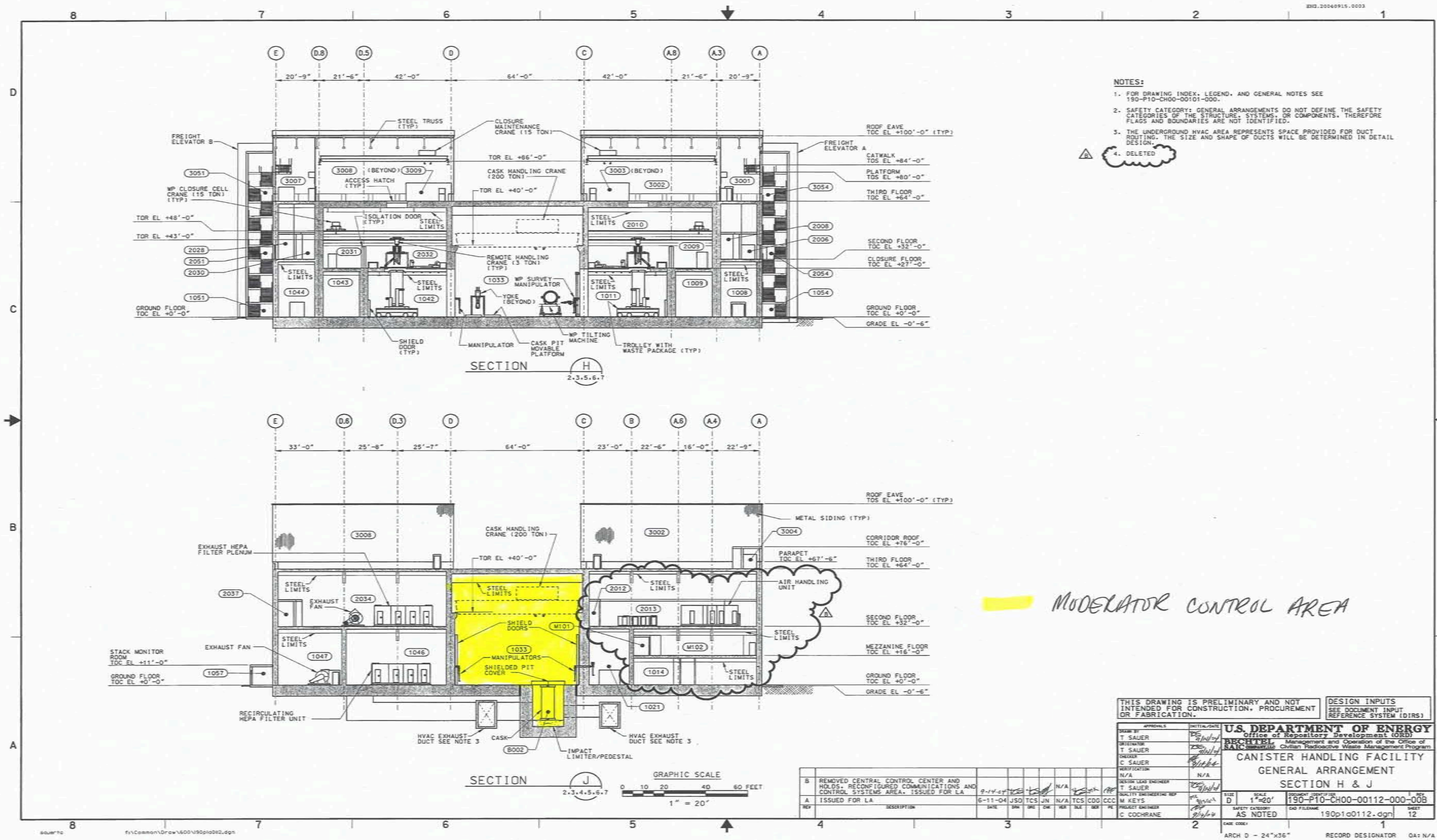
ARCH D - 24"x36"
RECORD DESIGNATOR QA: N/A


SECTION C
SECTION D
MODERATOR CONTROL AREA
U.S. DEPARTMENT OF ENERGY
Office of Repository Development (ORD)
BECHTEL SAIC
CANISTER HANDLING FACILITY
GENERAL ARRANGEMENT
SECTION C & D
190-P10-CH00-00109-000-00B
THIS DRAWING IS PRELIMINARY AND NOT INTENDED FOR CONSTRUCTION, PROCUREMENT OR FABRICATION.


NOTES:
1. FOR DRAWING INDEX, LEGEND AND GENERAL NOTES SEE 190-P10-CH00-00101-000.
2. SAFETY CATEGORY: GENERAL ARRANGEMENTS DO NOT DEFINE THE SAFETY CATEGORIES OF THE STRUCTURE, SYSTEMS, OR COMPONENTS. THEREFORE FLAGS AND BOUNDARIES ARE NOT IDENTIFIED.
3. THE UNDERGROUND HVAC AREA REPRESENTS SPACE PROVIDED FOR DUCT ROUTING. THE SIZE AND SHAPE OF DUCTS WILL BE DETERMINED IN DETAIL DESIGN.
ROOF EAVE EL +100'-0"
CORRIDOR AND STAIR #3 ROOF TOS EL +76'-0"
THIRD FLOOR TOC EL +64'-0"
SECOND FLOOR TOC EL +32'-0"
GROUND FLOOR TOC EL +0'-0"
GRADE EL -0'-6"
ELEVATOR EQUIPMENT ROOM (BEYOND)
CLOSURE MAINTENANCE CRANE (15 TON)
STEEL STRUCTURE
TOR EL+86'-0"
PLATFORM TOS EL+84'-0"
ROLL-UP DOOR
PLATFORM TOS EL+80'-0"
PLATFORM AND CATWALK OR FOR ACCESS TO ELEVATOR EQUIPMENT ROOM ONLY
PARAPET TOC EL +67'-6"
STEEL LIMITS (TYP)
RECIRCULATING HEPA FILTER UNIT (TYP)
EXHAUST FAN (TYP)
AIR HANDLING UNIT (TYP)
RECIRCULATING FAN (TYP)
GRADE EL -0'-6"
SEE NOTE 3
SECTION E
GRAPHIC SCALE
1" = 20'
THIS DRAWING IS PRELIMINARY AND NOT INTENDED FOR CONSTRUCTION, PROCUREMENT OR FABRICATION.
DESIGN INPUTS
SEE DOCUMENT INPUT REFERENCE SYSTEM (DIRS)
B REMOVED HOLD, ISSUED FOR LA
A ISSUED FOR LA 6-11-04
U.S. DEPARTMENT OF ENERGY
Office of Repository Development (ORD)
BECHTEL SAIC Management and Operation of the Office of Civilian Radioactive Waste Management Program
CANISTER HANDLING FACILITY
GENERAL ARRANGEMENT
SECTION E
DRAWN BY T SAUER
ORIGINATOR T SAUER
CHECKER C SAUER
VERIFICATION N/A
DESIGN LEAD ENGINEER T SAUER
QUALITY ENGINEERING REP M KEYS
PROJECT ENGINEER C COCHRANE
SIZE D
SCALE 1"=20'
DOCUMENT IDENTIFIER 190-P10-CH00-00110-000-00B
SAFETY CATEGORY AS NOTED
CAD FILENAME 190p1o0110.dgn
SHEET 10
ARCH D - 24"x36"
RECORD DESIGNATOR
QA: N/A


NOTES:
1. FOR DRAWING INDEX, LEGEND AND GENERAL NOTES SEE 190-P10-CH00-00101-000.
2. SAFETY CATEGORY: GENERAL ARRANGEMENT DRAWINGS DO NOT DEFINE THE SAFETY CATEGORIES OF THE STRUCTURES, SYSTEMS OR COMPONENTS. THEREFORE FLAGS AND BOUNDARIES ARE NOT IDENTIFIED.
SECTION F
SECTION G
WP AND CANISTER HANDLING MAINTENANCE CRANE (15 TON)
WP AND CANISTER HANDLING CRANE (100 TON)
TELESCOPING MANIPULATOR
ROLL-UP DOOR
SHIELDED HATCH
WASTE PACKAGE TRANSPORTER
YOKE STAND
SHIELD DOOR
MANIPULATOR & VIEWING WINDOW
WP/PALLET LIFTING YOKE
TURNTABLE
RECIRCULATING FANS
RECIRCULATING HEPA FILTER UNIT (TYP)
AIR HANDLING UNIT
BATTERY RACK
STEEL LIMITS
ROOF EAVE TOS EL +96'-0"
PARAPET TOC EL +67'-6"
CORRIDOR ROOF TOS EL +76'-0"
THIRD FLOOR TOC EL +64'-0"
SECOND FLOOR TOC EL +32'-0"
GROUND FLOOR TOC EL +0'-0"
GRADE EL -0'-6"
TOR EL +82'-0"
TOR EL +40'-0"
GRAPHIC SCALE
1" = 20'
THIS DRAWING IS PRELIMINARY AND NOT INTENDED FOR CONSTRUCTION, PROCUREMENT OR FABRICATION.
DESIGN INPUTS
SEE DOCUMENT INPUT REFERENCE SYSTEM (DIRS)
U.S. DEPARTMENT OF ENERGY
Office of Repository Development (ORD)
BECHTEL SAIC COMPANY, LLC Management and Operation of the Office of Civilian Radioactive Waste Management Program
CANISTER HANDLING FACILITY
GENERAL ARRANGEMENT
SECTION F & G
DRAWN BY J OLSEN
ORIGINATOR T SAUER
CHECKER J NEWSOME
VERIFICATION N/A
DESIGN LEAD ENGINEER T SAUER
QUALITY ENGINEERING REP L ABERNATHY
PROJECT ENGINEER C COCHRANE
SIZE D
SCALE 1"=20'
DOCUMENT IDENTIFIER 190-P10-CH00-00111-000-00A
SAFETY CATEGORY AS NOTED
CAD FILENAME 190p1a0111.dgn
SHEET 11
A ISSUED FOR LA
ARCH D - 24"x36"
RECORD DESIGNATOR
QA: N/A


SECTION H
2,3,5,6,7
SECTION J
2,3,4,5,6,7
MODERATOR CONTROL AREA
NOTES:
1. FOR DRAWING INDEX, LEGEND, AND GENERAL NOTES SEE 190-P10-CH00-00101-000.
2. SAFETY CATEGORY: GENERAL ARRANGEMENTS DO NOT DEFINE THE SAFETY CATEGORIES OF THE STRUCTURE, SYSTEMS, OR COMPONENTS. THEREFORE FLAGS AND BOUNDARIES ARE NOT IDENTIFIED.
3. THE UNDERGROUND HVAC AREA REPRESENTS SPACE PROVIDED FOR DUCT ROUTING. THE SIZE AND SHAPE OF DUCTS WILL BE DETERMINED IN DETAIL DESIGN.
4. DELETED
CASK HANDLING CRANE (200 TON)
SHIELD DOORS
MANIPULATORS
SHIELDED PIT COVER
GRAPHIC SCALE
1" = 20'
THIS DRAWING IS PRELIMINARY AND NOT INTENDED FOR CONSTRUCTION, PROCUREMENT OR FABRICATION.
DESIGN INPUTS
SEE DOCUMENT INPUT REFERENCE SYSTEM (DIRS)
B REMOVED CENTRAL CONTROL CENTER AND HOLDS. RECONFIGURED COMMUNICATIONS AND CONTROL SYSTEMS AREA. ISSUED FOR LA
A ISSUED FOR LA 6-11-04 JSO TCS JN N/A TCS CDG CCC
DRAWN BY T SAUER
ORIGINATOR T SAUER
CHECKER C SAUER
VERIFICATION N/A
DESIGN LEAD ENGINEER T SAUER
QUALITY ENGINEERING REP M KEYS
PROJECT ENGINEER C COCHRANE
U.S. DEPARTMENT OF ENERGY
Office of Repository Development (ORD)
BECHTEL SAIC
Management and Operation of the Office of Civilian Radioactive Waste Management Program
CANISTER HANDLING FACILITY
GENERAL ARRANGEMENT
SECTION H & J
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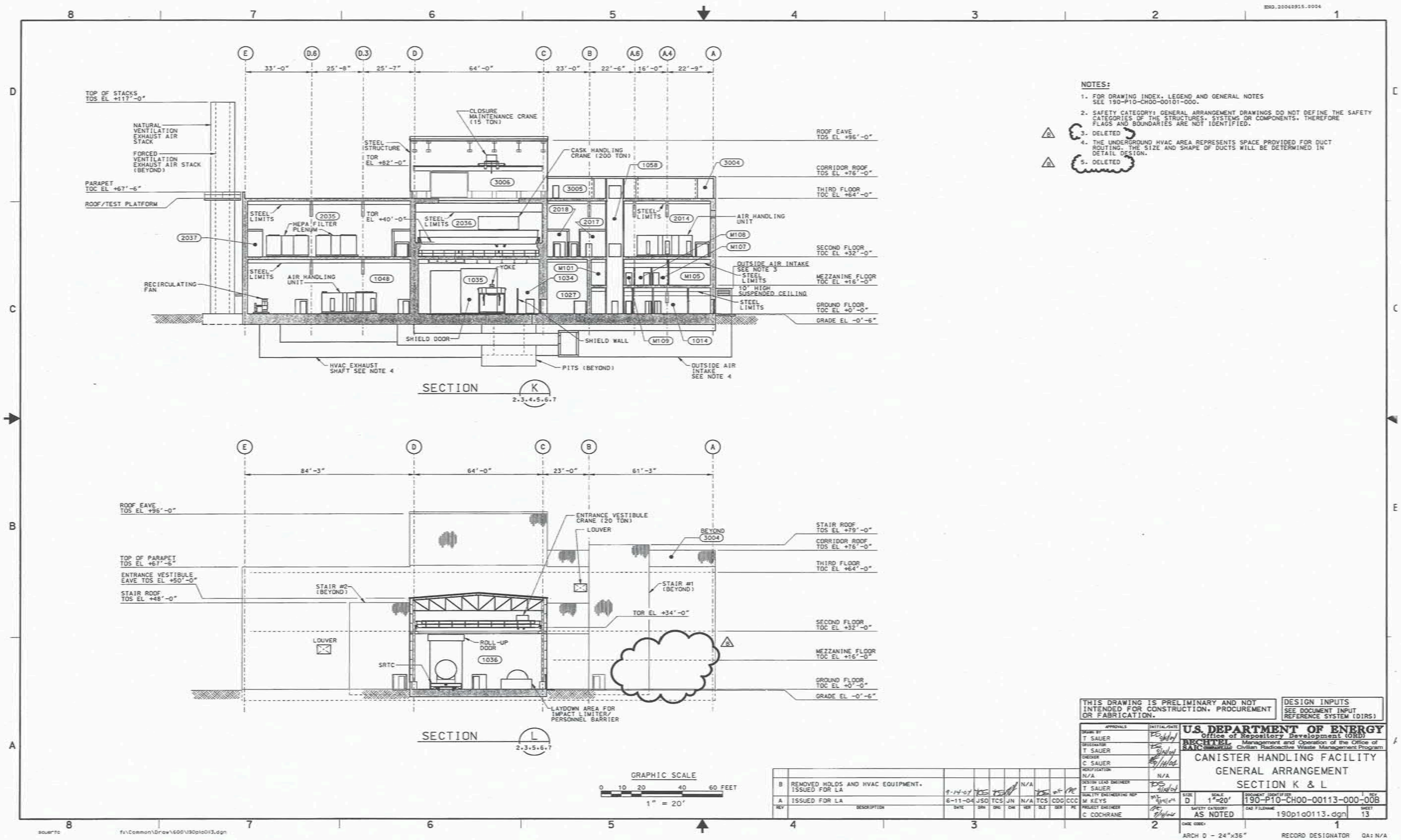
AS NOTED 190p1c0112.dgn 12
ARCH D - 24"x36"
RECORD DESIGNATOR OA: N/A


SECTION K
2.3.4.5.6.7
SECTION L
2.3.5.6.7
TOP OF STACKS TOS EL +117'-0"
NATURAL VENTILATION EXHAUST AIR STACK
FORCED VENTILATION EXHAUST AIR STACK (BEYOND)
PARAPET TOC EL +67'-6"
ROOF/TEST PLATFORM
RECIRCULATING FAN
CLOSURE MAINTENANCE CRANE (15 TON)
CASK HANDLING CRANE (200 TON)
STEEL STRUCTURE
HEPA FILTER PLENUM
AIR HANDLING UNIT
STEEL LIMITS
YOKE
SHIELD DOOR
SHIELD WALL
HVAC EXHAUST SHAFT SEE NOTE 4
PITS (BEYOND)
OUTSIDE AIR INTAKE SEE NOTE 4
OUTSIDE AIR INTAKE SEE NOTE 3
10' HIGH SUSPENDED CEILING
ROOF EAVE TOS EL +96'-0"
CORRIDOR ROOF TOS EL +76'-0"
THIRD FLOOR TOC EL +64'-0"
SECOND FLOOR TOC EL +32'-0"
MEZZANINE FLOOR TOC EL +16'-0"
GROUND FLOOR TOC EL +0'-0"
GRADE EL -0'-6"
TOP OF PARAPET TOS EL +67'-6"
ENTRANCE VESTIBULE EAVE TOS EL +50'-0"
STAIR ROOF TOS EL +48'-0"
STAIR ROOF TOS EL +79'-0"
ENTRANCE VESTIBULE CRANE (20 TON)
LOUVER
STAIR #1 (BEYOND)
STAIR #2 (BEYOND)
TOR EL +34'-0"
ROLL-UP DOOR
SRTC
LAYDOWN AREA FOR IMPACT LIMITER/ PERSONNEL BARRIER
GRAPHIC SCALE
1" = 20'
NOTES:
1. FOR DRAWING INDEX, LEGEND AND GENERAL NOTES SEE 190-P10-CH00-00101-000.
2. SAFETY CATEGORY: GENERAL ARRANGEMENT DRAWINGS DO NOT DEFINE THE SAFETY CATEGORIES OF THE STRUCTURES, SYSTEMS OR COMPONENTS, THEREFORE FLAGS AND BOUNDARIES ARE NOT IDENTIFIED.
3. DELETED
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5. DELETED
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CHECKER C SAUER
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QUALITY ENGINEERING REP M KEYS
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GENERAL ARRANGEMENT
SECTION K & L
SIZE D SCALE 1"=20' DOCUMENT IDENTIFIER 190-P10-CH00-00113-000-00B
SAFETY CATEGORY AS NOTED
CAD FILENAME 190p1o0113.dgn
SHEET 13
ARCH D - 24"x36"
RECORD DESIGNATOR QA: N/A